ALLIS-CHALMERS Electrical REVIEW

Fourth Quarter, 1949

A completely rebuilt motor is tested with dynamometer. This machine applies low voltage and overloads exactly as in actual usage.

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ALLIS-CHALMERS

DIMENSIONS of this four-row "slice" of the low pressure blading for a 107,000-kw turbine are being checked by micrometer on the Allis-Chalmers erecting floor. The largest stationary blades in the turbine are shown in the foreground. They will direct steam to the last and largest moving blade row, which is 12 feet in diameter. Steam pressure drop in the turbine is 1250 psi. Temperature drop is nearly 1000 degrees F.

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Allis-Chalmers

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ALLIS-CHALMERS Electrical REVIEW

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Contents

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A Half Century of Oil Circuit Breakers

by K. P. SEELY

Circuit Breaker Section
Allis-Chalmers Mfg. Co.
Boston, Mass.

***50 Years Ago*... an engineer with an idea, Dr. Leonard L. Elden, and a man with the means to put it in action, Sears B. Condit, Jr, set out to fill a need. The story of the circuit breaker industry they set in motion embraces the half-century history of Allis-Chalmers Boston Works.**

DEVELOPMENT AND EXPANSION of the electric power industry in the past half century has been amazing. Its contribution to industrial progress, and thereby the high standard of living and national well being, is generally and truly appreciated. However, the power circuit breaker and its importance in the development and operation of huge interconnected power systems is not as well known.

Two hundred and sixteen billion kilowatt hours—nearly four billion dollars worth of electrical power—were consumed in the United States during 1947 alone. Without power circuit breakers even a small fraction of this consumption would have been phenomenal. In fact, without these vital protective devices, electric power service as it is known today would be impossible, since the operation of even small power systems would be impractical.

A true appreciation of the power circuit breaker involves some understanding of the conditions preceding its invention, and of the progressive steps in its subsequent development. Since the first, and still the most important, type of power circuit breaker was the tank-type oil breaker, this type is naturally the theme of our story.

Although obviously it is impossible to cover all phases of the development and use of oil circuit breakers in a single article, a general outline of the highlights of the evolution of typical apparatus is given here. While insofar as possible, the apparatus highlights presented are typical of general practice, the particular examples and illustrations largely refer to apparatus produced by the Company with which the writer is associated.

AC spurred breaker improvement

In the early years of the electric power industry when operating voltages were low and generators were small—a few hundred kilowatts capacity at best—air circuit breakers and fuses were adequate to clear such faults as were encountered.

However, the introduction of alternating current generators in the 1880's, and subsequent rapid increase in size and use, by 1897 brought about problems in circuit interruption for which the air circuit breakers and fuses of that time did not provide adequate protection.

The following extract from the Introduction to a catalog published about 1900 is helpful in giving an insight into the conditions then prevailing.

"The introduction of alternating current apparatus for general use in central stations was followed by numberless accidents and interruptions to the service supplied, largely due to the unsuitable protective and switching devices used.

"A study of the various methods used in fairly recent installations shows devices having breaks up to several feet in length, with large barriers between individual lines to prevent arcing between them.

"Another method is the employment of fuse shunted switches or circuit breakers which depend on the efficiency of the fuses for their reliability. In some stations we see the attendant waving a long pole, having a contact on the end which normally is inserted in a receptacle high up on the wall, but which is removed and waved around in the air to break the arc when it is desired to interrupt that particular line. That these methods fail at critical moments is a well known fact, and if the inner history of many stations operating large units was laid bare it would show many such failures."

From this extract it is apparent that expansion and growth in the electrical industry demanded an improved interrupting device; and the answer came in the invention of the oil circuit breaker.

The late Dr. Leonard L. Elden, in describing the events leading to his invention of the first power circuit breaker in America, mentioned having observed that "carbon brushes soaked in oil or impregnated with lubricating materials sparked less on the commutators of d-c machines than non-lubricated brushes. 'Do these conditions in any way indicate usefulness

of oil as an arc-quenching medium in switching apparatus?' We often wondered."

First power circuit breaker

So when Dr. Elden was faced with the problem of protecting the generators and other apparatus associated with a new "large" generating station of 9,000-kw capacity, he did not stop at wondering, but began the experiments which led to the development of the breaker shown in Figure 1, a number of which were installed in the "L" Street Station of the Boston Electric Light Company in 1898.

Although employed by the Boston Electric Company in charge of all electrical equipment, Dr. Elden, wishing to share his discovery with other utilities, arranged for their manufacture by Sears B. Condit, who formed a company under his own name in 1899[1]. The first type offered commercially is shown in Figure 2.

The type "A" breaker, as it was called, was rated 400 amperes, 4,000 volts, arranged for mounting on the rear of a switchboard panel. As was typical of all early breakers, it was designed to handle faults on a certain class of applications, but had no specific assigned interrupting capacity rating.

Many pioneer features retained

At first glance, the type "A" breaker appears to be nothing more than an up-break knife switch immersed in a bucket of oil. However, some of its principles are used in the most modern oil circuit breakers:

(a) Both the stationary and movable conductors were rigidly supported near the point of contact to avoid difficulties from electro-magnetic forces produced between the conductors by high currents. The conductors form a ¾ turn loop, and current flowing downward in one stud and upward in the other causes a concentration of magnetic forces inside the loop. This creates a repulsive force on the arcs drawn at the contacts tending to blow them outward and thus elongate them. Arc elongation is one of the important principles of circuit interruption.

(b) The knife-blade and jaw contacts, besides giving firm contact pressure, provided two parallel paths to conduct current in the same direction to the blade. Thus the internal magnetic field, particularly at high currents, would force the jaws together, tending to offset the "throw-off" effect.

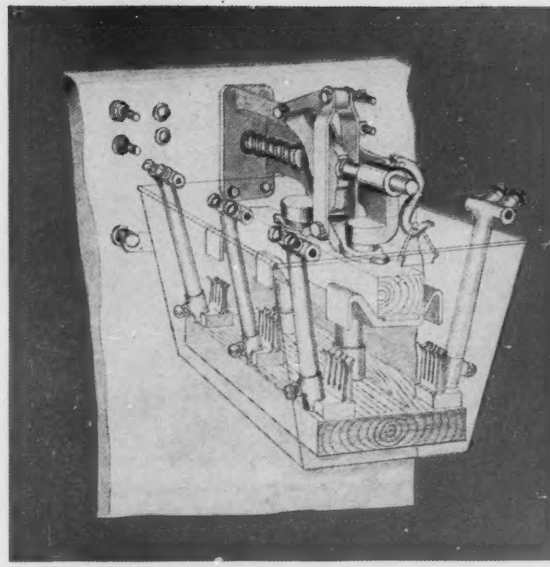
(c) A (wooden) cover, in addition to protecting the oil from dust, limited oil throw and supplied a secondary support for the conductors.

(d) Straight line motion of the movable member was insured by two guide rods extending upwards from the wooden base on which the stationary contacts were mounted.

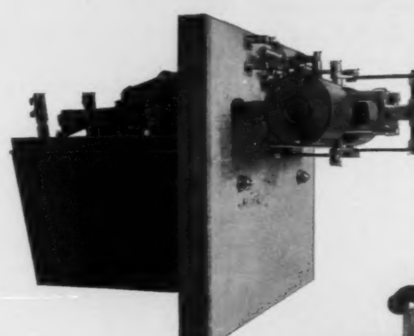
(e) The operating mechanism had a toggle linkage so arranged that it was on, or slightly over, center with the breaker closed. An impulse applied to the mid-point of the toggle would trip the breaker by forcing the toggle off-center and allowing the contacts to be opened by pressure from springs which had been compressed during closing. Toggles are still widely used in oil circuit breakers.

(f) The tripping impulse was applied by a trip coil. This was either a series type, with consequent high voltage on the front of the switchboard, or one operated from a current transformer.

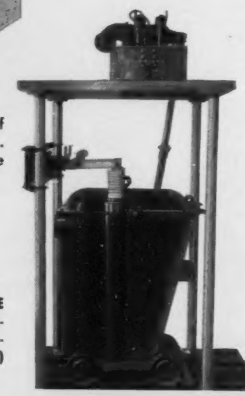
[1]This firm subsequently became the Boston Works of the Allis-Chalmers Mfg. Co.



FIRST OIL CIRCUIT BREAKER in America. A number of these breakers were installed in 1898 in the Boston Electric Light Company's L Street Station. **(FIGURE 1)**



FIRST COMMERCIAL MODEL of breaker in Figure 1 looked like this. Note that breaker is mounted on the rear of the panel. **(FIGURE 2)**



FIRST REMOVABLE TRUCK TYPE breaker had primary disconnects, separately mounted operator, to ease inspection and maintenance. **(FIGURE 3)**

Other oil circuit breakers were built about the same time in Europe, including 16,000-volt breakers built for a Palermo, Italy, power station, another built by Ferranti, and experiments were made at a New York power station in 1898 which led to the development of an early low oil volume, or so-called H-pot breaker, made available in 1899. This device later formed the basis for the explosion pot interrupting device used in tank-type breakers.

First wheels simplified inspection

By 1909, the power handled in generating plants and substations had increased considerably, and the tank-per-phase circuit breakers which had been developed were too heavy for mounting on switchboards. Consequently, the type "F" breaker, Figure 3, was introduced for cell mounting, equipped with wheels and primary disconnects. The operating mechanism was separately mounted so that the oil circuit breaker could be withdrawn for inspection or repair without disturbing the control connections.

This truck-type breaker was a forward step. Inspection and repairs were simplified and a high cell was not necessary to permit tank removal. As was to be expected, the higher capacity breaker required a more powerful operating device, and a clapper type of solenoid was developed.

In 1910, a high voltage outdoor breaker was introduced. This 70 kv breaker had dry-type porcelain bushings and a horizontal rotary break contact arrangement. Figure 4 shows a test setup of this breaker. In service the hand operated faceplate was protected by a weatherproof housing.

AIEE creates standards

During the period from 1915 to 1920, which included World War I, electrical energy consumption nearly tripled. As the number and size of generating units increased, oil circuit breaker troubles revealed that interruption of heavy currents under oil was not as simple as it had been thought to be.

A paper, presented before AIEE by G. A. Burnham*, E. M. Hewlett, and J. N. Mahoney in 1918, dealt with the rating and selection of oil circuit breakers. The need for some form of standard was pointed out.

The Electric Power Club adopted in 1919 what in modern terminology was the 0-2-minute-CO duty cycle which specified that a breaker should interrupt its maximum rating on this duty cycle. No restrictions were placed on the performance, other than that the breaker should interrupt its rating "and then be in condition to be closed and carry its rated current until it is practical to inspect it and make necessary adjustments." Flame and oil throwing were still permissible so long as they did not interfere with the performance of the duty cycle.

*Formerly manager Allis-Chalmers Boston Works.

Hollow walls absorb arc energy

The energy absorption principle, first used in 1919, was combined with an oil blast feature in a unique design of breaker shown in Figures 5a and 5b.

As may be seen from the illustrations, the breaker tank is so constructed as to provide an energy absorption chamber in the tank walls. Oil is free to move into this chamber at the bottom of the tank only. During the process of interruption the pressure caused by the formation of an arc bubble upon parting of the breaker contacts forces oil downward and outward into the chamber in the tank walls where its energy is temporarily absorbed in compressing the air trapped in the upper portion of the chamber.

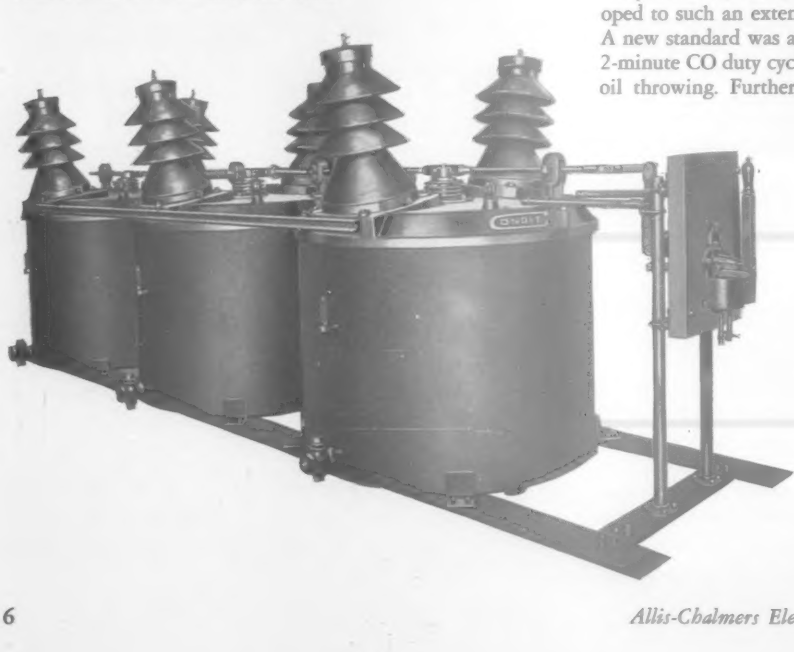
When the pressure in the main tank is reduced by the cyclic reduction of current, the energy stored in the compressed air expels the oil back into the bottom of the tank and upward past the downward moving arcing contacts tending to carry with it the gas bubble.

This design might be considered a forerunner of the oil blast and expulsion port developments which followed some years later.

Splitting up the arc

Within two years after the development of the energy absorption principle, a multiple-break form of contact construction (Figure 6) was introduced. The breaker shown was built in ratings of 600 to 1,200 amperes for 15 kv and had an interrupting capacity of 520,000 kva. Four breaks in series had the effect of splitting up the arc into a number of smaller arcs. As the total break distance increased in proportion to the number of breaks, the effective speed of contact separation was greatly increased. Total heat absorption by the contacts was also multiplied. The net effect was a considerable increase in interrupting efficiency.

By October, 1924, the electrical power industry had developed to such an extent that the 1919 duty cycle was obsolete. A new standard was adopted, in modern terminology, the CO-2-minute CO duty cycle, which banned flame throwing but not oil throwing. Furthermore, the standard required that, after



70-KV OUTDOOR OIL BREAKER, vintage 1910, had dry porcelain bushings and rotary horizontal break contacts. Note huge volume of oil used in early tanks compared with modern breakers. **(FIGURE 4)**

the specified duty, the breaker should be "in substantially the same mechanical condition as before." The electrical condition specification required that "after performing at or near its interrupting rating, the interrupting ability of the breaker may be materially reduced and it is not to be inferred that it may be reclosed after such performance without inspecting and if necessary making repairs."

Within three years after the adoption of the new standard, a magnetic blowout method of circuit interruption was introduced. Figure 7a shows an oil circuit breaker combining the magnetic blowout feature and multiple breaks. A $1\frac{1}{2}$ turn magnetic blowout coil (Figure 7b) introduced into each movable arcing contact circuit created a magnetic field which forced the arc at each contact outward into the oil. As the magnetic field increased in proportion to the short circuit current, the effect of the magnetic blowout increased, and exceptionally high speed interruption was thus obtained at the higher currents.

The early 1930's may be considered as marking the close of the plain-break power circuit breaker era.

Proof-testing becomes essential

Prior to 1920, no American manufacturer was equipped to proof-test his product—but, through co-operation with the public utility industry, testing stations were made available on several of the large systems. Tests made at these locations indicated the necessity of manufacturers providing their own test facilities if sufficiently rapid progress was to be made in breaker development. As a result, breaker manufacturers spent large sums of money during the next several years equipping high capacity testing laboratories.

It had become apparent, even from these early field tests, that the throwing of oil and gases, and the development of high internal pressures, could not be solved by the use of combinations of gaskets and oil separators alone, nor could the problem of meeting the requirements for much higher interrupting capacities be solved simply by making breakers bigger and stronger.

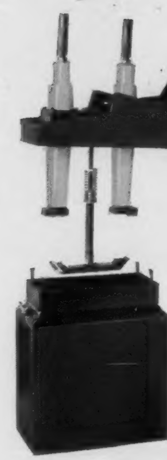
During this period, an intensive testing campaign was prosecuted to determine the effects and relationships of the then known factors, such as mechanical speed, head of oil, ratio of expansion space to rating, quick-break contacts, multi-break, electro-magnetic, and thermal effects, etc., on the arc energy expended within the breaker to dissociate and displace the oil within the breaker tanks.

This intensive research testing program conducted in the late 1920's by the manufacturers resulted in the turn away from plain break breakers and the advent of the modern breaker era in the early 1930's.

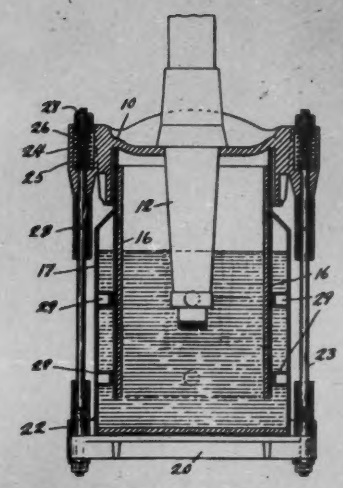
Controlling the arc energy

This analytical test program indicated that the solution of the problem lay in the reduction of arc energy, and that by enclosing the arc within a small, strong secondary enclosure, the arc energy and arcing time could be greatly reduced. This would limit the pressure propagated to the tank, and the reduced oil and contact deterioration resulting from the reduced arc energy would make it possible to reduce the frequency and extent of maintenance.

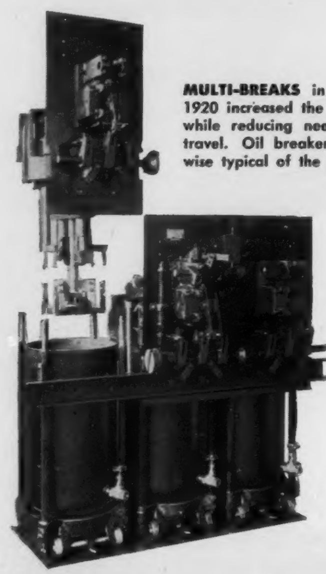
During the five-year period from 1928 to 1933, three major types of modern arc-enclosing and interrupting devices for



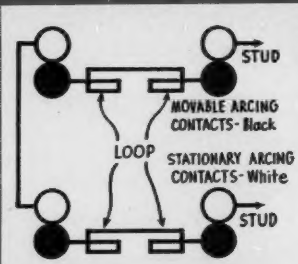
ENERGY ABSORPTION and oil blast principles were employed in this 1919 breaker. **(FIG. 5a)**

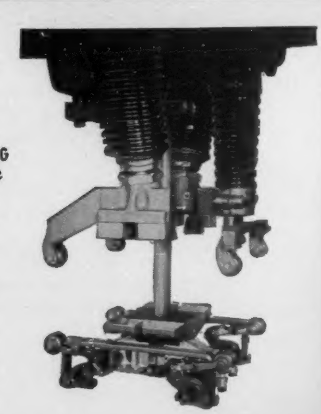


HOLLOW WALLS with air pocket relieved expanding oil in this design breaker at left and in patent drawing above. Device was effective. **(FIG. 5b)**

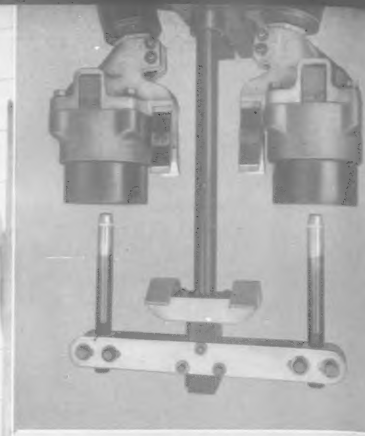


MULTI-BREAKS in series used about 1920 increased the effective arc length while reducing need for long contact travel. Oil breakers shown are otherwise typical of the period. **(FIGURE 6)**

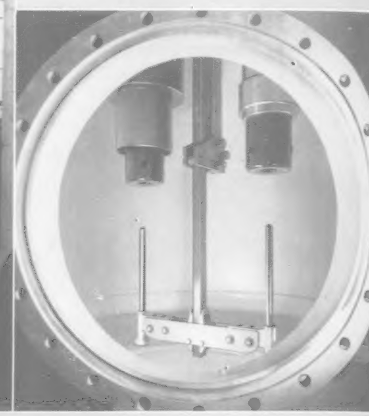




MAGNETIC BLOWOUT was combined with multiple breaks to increase arc length and interrupting speed, particularly at high currents. Diagram above shows magnetic loops. At left is breaker contact design used about 1927. **(FIGS. 7a and 7b)**



EARLY IMPROVED RUPTOR device mounted on each bushing stud used arc energy for extinction of arc. **(FIG. 8)**



SIZE COMPARISON of modern breakers shows how size of new design of 138-kv unit at left has been reduced in size from previous design at right. Oil volume was thus reduced 40 percent in one step. Note how protruding parts have been eliminated from the outside surface of the modern breaker. **(FIG. 9)**

MODERN TURBO RUPTOR device utilizes best principle of design learned through years of development. **(FIGURE 10)**

tank-type oil breakers were made available: the Deion Grid, the Oil Blast Explosion Chamber, and the Ruptor Interrupting Device.

Figure 8 shows an improved model of the original Ruptor device and one which has been in use on eight-cycle breakers for a number of years. It consists fundamentally of an arc enclosing chamber with an upper part, or hood, which includes the stationary arcing contact assembly, and a lower shell part which includes an oil reservoir, or pressure generating chamber, and a throat, or passage of special shape for the movable arcing contact, which also may be termed the arc extinguishing chamber.

The movable arcing contact, which is of the bayonet form, enters the Ruptor Chamber at the bottom of the throat passage and moves upward until it makes contact with the stationary contact assembly in the hood, into the tulip segments of which it slides with a wedge action.

A separate Ruptor arc interrupting device is mounted on each bushing stud so that a three-pole breaker has six such devices.

Confined arc extinguishes quicker

When the oil circuit breaker is tripped, the movable bayonet starts moving downward in the tulip-type stationary arcing contacts with rapidly accelerating speed under the impulsion of powerful accelerating springs and gravity.

Upon parting of the contacts, an arc is drawn within the pressure generating chamber, resulting in the generation of a gas bubble in which, because of the inherent confinement of the pressure chamber, the pressure quickly builds up to a magnitude sufficient for efficient interruption. This pressure also tends to increase the contact opening speed.

Because of the high pressure developed, the intensity of heat in the arc core and relatively cool surface of the bubble, a high degree of turbulence exists within the bubble. As a result, cool vapors and gases are continually mixing with extremely hot intensely ionized gases with a chilling effect that produces continuous deionization.

While the bubble pressure has been building up, the bayonet has been moving downward at high speed, extending the arc into the restricted throat passage. The high pressure built up in the arc bubble forces the oil in the pressure chamber into the throat passage with a swirling turbulent motion and envelops the arc with a greatly intensified deionizing action.

Because of the conformation of the throat, this swirling turbulent deionizing action progressively increases as the bayonet withdraws, becoming increasingly effective as current approaches zero. Interruption is achieved at an early current zero.

By the early 1930's, the Industry had been able to standardize on eight cycles of interrupting time whereas 12 to 20 cycles were required by earlier breakers. The standard reclosing interval was reduced from two minutes to fifteen seconds and the CO-2-minute-CO duty cycle became obsolete, being superseded in 1934 by the CO-15-second-CO duty cycle of The National Electrical Manufacturers Association.

Even this reduced reclosing interval was generally unsatisfactory as it was still necessary to restart motors, and certain industrial processes might be damaged by the stoppage. Reclosing after trip-out without intentional time delay, resulting in a reclosing interval of about one second, began to be practiced; but even this interval was too long for some systems. Shortly the need for reclosing of high voltage transmission breakers at still higher speeds to preserve synchronism between two generating sources also became apparent.

Investigation was undertaken in the middle 30's to determine how quickly service must be restored to keep induction motors on the line and provide desired system stability. As a result of this investigation, standard reclosing speeds were set up at from 30 to 45 cycles, and subsequently a fast reclosing speed of 20 cycles was made available for high voltage breakers.

The reclosing speed of 20 cycles was not obtainable with solenoid operators then in general use and the need for faster operators led oil circuit breaker design engineers to investigate the possibilities of compressed air as a means for solving the problem.

Automatic reclosing speeded

Experimentation revealed that compressed air would provide an ideal means for obtaining the necessary closing speed. The use of compressed air for opening did not, however, offer any improvement over conventional opening means.

What is believed to be the first modern commercial pneumatically-operated breaker in America was completed and installed early in 1940. Although not required to reclose rapidly, this 69-kv, 500,000-kva interrupting capacity breaker had a reclosing time of 20 cycles. It was followed in the same year by a pneumatically-operated 115-kv breaker, also capable of 20-cycle reclosing. Development and improvement has continued during succeeding years concurrently with the increase in demand for pneumatically-operated breakers.

Allis-Chalmers has consistently maintained the mechanical trip-free feature, while others have generally substituted a pneumatically trip-free arrangement to obtain fast release on CO operations.

Prior to 1942, insulation levels for oil circuit breakers were governed by the 60-cycle withstand requirement of the AIEE and NEMA Standards. However, the fact that insulation failures in the majority of cases were due to impulse voltages of brief duration indicated the need for an impulse rating, and led to the adoption in 1942 by NEMA of the present standard insulation levels for power circuit breakers which specify an impulse withstand voltage, in addition to the 60-cycle withstand voltage.

Five-cycle operation of high voltage outdoor breakers became available in the early 1940's and was made standard for breakers 115 kv and above in 1944. Some breakers for three-cycle operation were available as early as 1940.

With the continual improvement in interrupting devices came increases in interrupting capacity, until today five million-kva breaker ratings at the higher voltages are standard, and interrupting capacities of 10 million kva at 230 kv are now projected. These breakers are to be arranged for three-cycle operation, as this highest operating speed is now standard for the extremely high voltages and interrupting capacities.

Another important factor in the evaluation of the present-day breaker is physical size. Up until several years ago, as interrupting capacity requirements became greater—high voltage breakers grew larger and larger. Breakers were built having three tanks, each as large as nine feet in diameter, and required as much as 15,000 gallons of oil for three phases. The handling of these large quantities of oil for maintenance became a considerable problem.

Bigger breakers get smaller

Now, although operating voltages, and particularly interrupting capacities, are still increasing, the physical size of modern oil circuit breakers is being reduced. In fact, at first glance the most striking thing about the modern high voltage tank-type oil circuit breaker is its size—or lack of it.

The best overall evaluation of the modern high voltage breaker may be had by examining a specific example. Figure 9 shows the latest design of a typical 138-kv, 2,500,000-kva, five-cycle, oil breaker (left) besides its immediate predecessor of the same rating, and clearly indicates the 40 percent size reduction which has been taken in one step. The advantages in space economy and reduction of the quantity of oil to be handled are obvious.

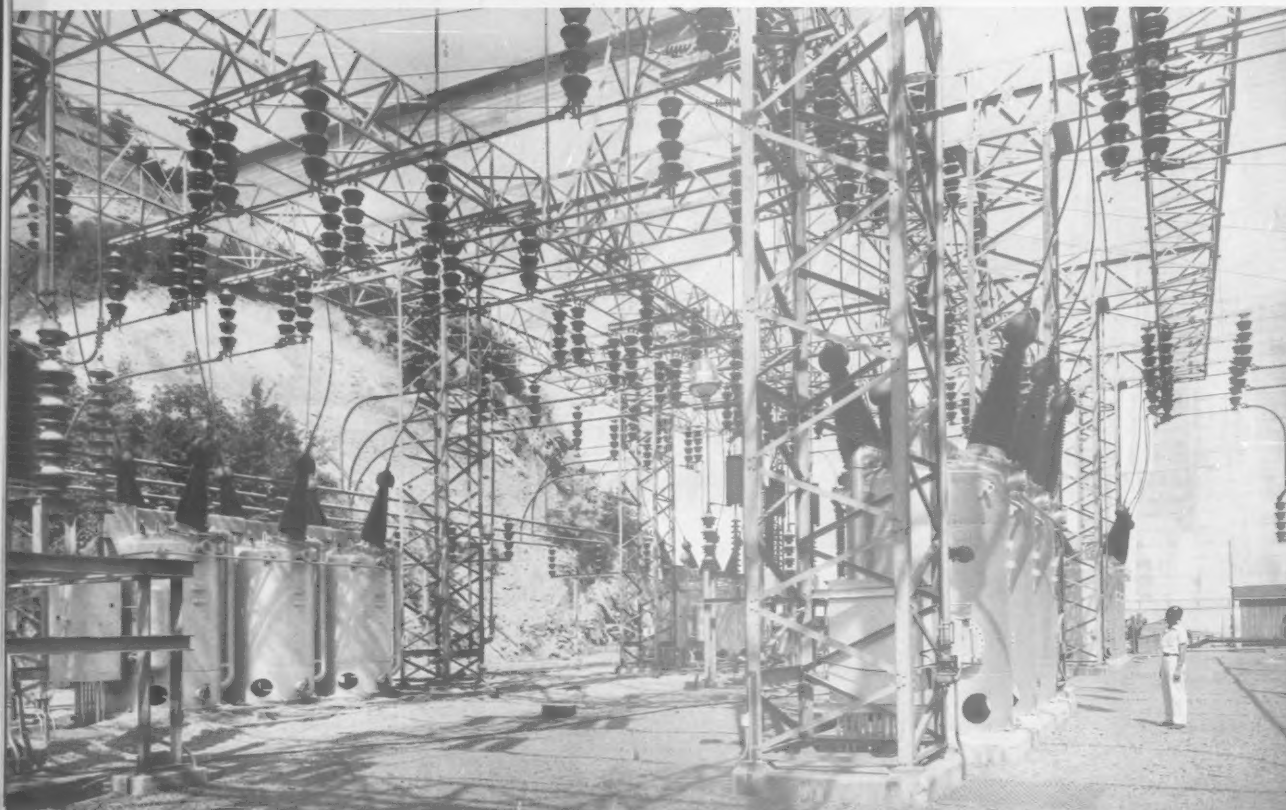
Much accent has been placed on smooth, compact, yet accessible utilitarian design. Typical examples are the elimination of protruding parts, such as current transformer conduit and tap boxes, access manholes of generous size and complete and readily accessible operator control panels.

Figure 10 shows the inside of a modern breaker tank and the absence of congestion, even in small tanks, resulting from the simplified rod guide structure. The use of high-strength aluminum alloy in the movable member, and of very strong bakelized plywood in the lift rod and guide structure has permitted such simplification. On each bushing is mounted a single-break Turbo-Ruptor arc enclosing and interrupting device with its shield member. The contacts themselves are of the simple and reliable bayonet and tulip type.

Continual redesign studies have made possible a number of minor, though important, improvements in breaker construction. For instance, current transformer wells are now provided with removable bottom closures, so that transformers may be removed or installed from the bottom, as well as from the top.

Many of the great strides that have been made in better circuit interruption facilities hinged around changes in the interrupting device itself. Today's Turbo-Ruptor device constitutes a major evolution from the original eight-cycle Ruptor unit, a low voltage design of which was shown in Figure 8, from which it differs functionally by reason of a much earlier and more efficient development of the interrupting function.

In operation, the Turbo-Ruptor unit sequence is similar to that described for the 8-cycle Ruptor unit, but an earlier and greatly enhanced attack upon the arc stream is provided by a much more efficient throat arrangement. A shallower pressure chamber aids in starting this throat action earlier. The steep-pitch multiple helical throat passage directs and distributes rapidly flowing increments of oil into the arc stream and around



HEART OF THE MODERN SWITCHYARD is the oil circuit breaker. These outdoor units incorporating the turbo system type of interrupting device are rated for 115-kv, 2,500,000-kva service. Oil breakers have come a long way from the first models of 1899. **(FIGURE 11)**

the bayonet contact tip, as it is drawn into and along the throat passage, with an intense swirling, turbulent action. This dynamic action disrupts and disperses the arc products in a highly efficient manner and effects circuit interruption at a very early current zero.

Figure 11 shows an installation of breakers rated 115 kv, 2,500,000 kva, equipped with Turbo-Ruptor devices.

Oilless breakers grow popular

While up to now we have dealt chiefly with tank-type oil circuit breakers, some mention should be made concerning recent trends toward oilless circuit breakers in the low and intermediate voltage field.

About 1934, manufacturers of oil circuit breakers in this country became interested in oilless and low oil volume breakers which have been developed in Europe, mainly because of the high oil prices existing in those countries.

Since that time development of oilless breakers has made considerable progress in this country in the indoor breaker field for 15 kv or less in the case of magnetic breakers and up to 34.5 kv in the case of air blast. Low oil volume breakers have found favor for certain high voltage high speed applications.

In the indoor moderate voltage field, oilless breakers have recently assumed domination of the field for some classes of application. Notable installations have also been made indoors at 23 and 34.5 kv.

What the future trend in oilless breaker application will be is not clear, but their use for some time to come seems likely to be confined to indoor applications, except where ultra-high speed reclosing requirements or other special considerations may dictate their use.

Looking ahead

The first oil circuit breaker was developed to meet the interrupting requirements of a 9,000-kw station, which lay somewhere between 50,000 and 100,000 kva. On the basis of the present-day performance requirements, however, the interrupting capacity of that first breaker would not exceed 15 to 25,000 kva.

Today a single generating plant of 1,000,000-kva capacity is in operation and a second unit of the same capacity is projected. Tank-type oil circuit breakers of 10,000,000-kva interrupting capacity at 230 kv are projected for this station.

Thus, the oil circuit breaker continues to demonstrate its seemingly endless ability to be adapted to the requirements of our ever-growing power networks. It remains then both old and new. It has come a long way since its birth in the form of that first oil circuit breaker built by Dr. Elden fifty years ago.

STANDARDS
help or hindrance?

by **H. V. NYE**
Switchgear Section
Allis-Chalmers Mfg. Co.

The author clears up a lot of misunderstandings in this short analysis of electrical industry standards today

A STANDARD can in general be defined as that which is established by authority, custom, or general consent as a measure of quality, value, or quantity. Consequently an apparatus standard becomes the yardstick by which we can measure its adequacy for the duty it performs, and compare it with other similar apparatus. It also serves as a minimum specification which must be met by any apparatus to which it applies.

Apparatus Standards in general usually come under one of three categories:

1. Rating Standards
2. Manufacturing Standards
3. Application Standards

All of these are likely to also include a section on definitions, which may be necessary in order to clarify the meaning of the Standards themselves.

It is easy to appreciate the need for rating standards. To make it clear what a 10-hp motor or a 1,200-amp switch is implies the necessity of stating the conditions under which such a rating is applicable.

Although it may not be so apparent, it is equally important to set up standards of manufacture and application if apparatus is to be generally suitable for satisfactory performance. The reasons for such standards are numerous, the primary ones being:

1. To protect the user in what he is buying,
2. To guide the manufacturer to know what is required,
3. To guide both in establishing an adequate but not excessive number of sizes and ratings to cover requirements.

Definitions are an important feature of any industry standard. Words are used to express thought, but unless a word means the same thing to the reader as to the writer it cannot convey the meaning intended. We are all careless in the language we employ and the words we use to express our meaning. In addition the English language frequently gives different meanings to the same word, and different shades of meaning. Consequently it is necessary to define, in any standard, just what is meant by the various terms employed. The usefulness and value of any standard may well hinge on the clarity with which its meaning is made plain through careful definition of the terms and phrases employed. This is frequently overlooked until a difference of opinion about the meaning of a standard is questioned or a difference of opinion arises in regard to its application.

Standards change constantly

To many engineers it is rather confusing when they find NEMA, AIEE, and ASA Standards covering the same type of apparatus, and they frequently ask why there should not be just one standard which can be used universally. Even engineers who have done considerable work on various standardizing committees frequently feel that too many organizations are trying to prepare standards. Logical as this desire may seem, it is easy to understand how these various standards came into existence and how difficult the problem is, when we consider what standards are and the reasons for their existence.

In the absence of any constituted authority which can arbitrarily impose standards on the electrical industry, the standards must come about by custom and general consent. As such, they may be considered as embodying the accumulated experience of both users and manufacturers.

Apparatus standards seldom remain fixed over long periods of time, but are constantly undergoing change. This is necessarily true from their nature. Reflecting, as they do, the user's experience with the apparatus in doing the required job, they are bound to change as the result of additional experience in use, and as a result of new requirements or a better understanding of such requirements.

Standardizing agency functions differ

AIEE Standards have generally been concerned largely with the basis of rating and acceptable test values to be sure apparatus meets the rating requirements. The Institute, being composed of engineers in all electrical lines, is a natural organization within which the user and manufacturer can cooperate on the production of basic standardization. Usually these standards do not greatly concern themselves with constructional arrangements or other manufacturing problems or with application rules.

NEMA Standards usually cover the same ground as the AIEE Standards, but also concern themselves with acceptable manufacturing and application standards applying to the class of apparatus involved. Usually they agree with and are governed by the engineering standards set up by AIEE, any differences in these points normally representing changing conditions and opinions which are ultimately reconciled and the standards brought in agreement. In the strictly manufacturing

and application standards they represent acceptable and satisfactory practice as determined by the experiences of the manufacturers.

ASA Standards are the result of a desire to get one American Standard which can be used as the standard of the industry. An ASA Standard is not usually produced until suitable standards have been brought out by other organizations such as NEMA and AIEE and the time appears ripe for an American Standard which will not require too frequent modifications. Due to the fact that ASA does have representation from all interested organizations, associations, manufacturers and individuals, the preparation of such a standard is necessarily a more lengthy procedure. This means that changes also are going to require more time. As a result, changes will frequently appear in NEMA standards before the corresponding changes are made by the ASA. At times this may cause some confusion but it can hardly be avoided.

Other organizations such as the Associated Edison Illuminating Companies and the Edison Electric Institute sometimes undertake various standardizing activities, but at the present time they usually try to coordinate their work with the three bodies above discussed, and such activities usually terminate in modifications in these standards.

Many standardization activities are carried on by joint committees formed between the above organizations, and frequently these joint committees bring about changes in all these related standards. One of the oldest and most active of such committees has been the AEIC-EEI-NEMA Joint Committee on Power Circuit Breakers. This committee recently brought about a complete revision of the rating tables on power circuit breakers in NEMA and ASA Standards.

Standards grow with the industry

Standards on Power Circuit Breakers represent an example of how changing conditions and better understanding of requirements result in modifications of the standards over a period of time.

When power stations were small and interrupting capacity was not great, the ability of circuit breakers was largely determined by their current-carrying capacity and their insulation for the service voltage. So long as they were able to interrupt the short circuits generally obtainable at that time no great need was felt for accurate determination of their capabilities under short circuit conditions. Their dependability and trouble-free operation under normal operating conditions was the paramount criterion of performance. Consequently the standards first prepared for this class of apparatus were not particularly exacting and were met largely by thermal and dielectric testing.

As systems became larger and the potential short circuit currents in event of a fault became greater, experience showed that many circuit breakers were inadequate for protecting the generating equipment and transmission lines in the case of short circuits on the system, and the requirements to be met by the breakers in this respect became an increasing concern on the part of users and manufacturers. Consequently the standards on power circuit breakers began to incorporate definite requirements for interrupting capacity and their ability to operate under such condition. These standards changed and became increasingly definite and rigid as experience with the apparatus accumulated, and as the ability of the manufacturers to measure the capacity of their breakers became greater.

Today, thanks largely to the studies and tests made on systems and in short circuit testing laboratories, the requirements to be met at any point of application is known, and the ability of a breaker to meet these conditions is capable of demonstration. As a result the standards on this apparatus now specifically cover many characteristics of the breaker which were not formerly covered. Standards on power circuit breakers now specifically cover, among others, the following:

1. System voltage
2. Maximum voltage at which it is designed to operate
3. Normal current rating
4. Maximum current it can carry for a short period
5. Maximum current it can carry for any period
6. Maximum current it can interrupt
7. Definite duty cycle for interruption
8. Condition of breaker after interruptions under duty cycle
9. Number of operations under load it can stand without maintenance
10. Maximum current it can close in against

All of these characteristics have been arrived at over many years by a pooling of user's experience and requirements with the ability of the manufacturers to produce apparatus to meet such requirements. The result has been a continually changing and evolvement of standards in keeping with the changing conditions and increased knowledge of the apparatus.

This same Joint Committee, by studying the desirability of circuit breaker ratings, has succeeded in reducing the number of such ratings required with a real saving to the industry.

Standards improve with time

Naturally the growth of standardization has not come about without mistakes or criticism. Today, however, there is no longer any question about the general need for standards in all branches of the electrical industry. The question has become rather, "How far shall this standard extend at this time?"

Best evidence of the continually growing acceptance of standards has been the formation of joint committees representing users and manufacturers in the very new branches of the electrical industry, almost at the outset of their existence.

Finding the proper balance between the disadvantages of premature standardization of an equipment and the uneconomic and inefficient situation that can result where standards are lacking has always been a problem, and will undoubtedly always remain one. Fortunately, each year adds to the experience on which engineers may draw for future guidance in good standardization practice. One thing the years have taught is that the only really successful standards are those that in the long run have been of real benefit to everyone—the user, the manufacturer, and to the public.

ELECTRONICS in the FOUNDRY?

by **BEN H. GRIFFITH, JR.**
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Definitely! More and better sand cores, reduced costs, production line operation, no storage racks, and cleaner, safer working conditions are among its leading features.

FOUNDRIES, like the rest of industry, are deep in the throes of a buyers' market with all its implications and problems. Demand is receding, competition is becoming increasingly keener. Product improvement and new methods to reduce costs are positive steps being taken to strengthen their position. Actually, entirely new layouts of foundry equipment are being considered. Old and new companies are becoming increasingly interested in up-to-date equipment that offers savings in total cost of castings by decreasing production costs.

There is also a more basic reason why foundries are considering modernization of facilities and equipment. While other industries are feeling an influx of workers, foundries face a diminishing labor pool. Experienced help is deserting for cleaner, healthier work. Excess heat, fumes, dust, and the nature of the labor itself makes foundry work undesirable. New blood is becoming more difficult to find. So, in addition to reducing production costs and increasing product quality, new equipment and methods are being sought which will clean up and improve working conditions.

Electronics transforms foundry

The gradually widening acceptance of electronic equipment as a practical and valuable industrial tool by other industries is extending into the foundry field. Now past the development stage and proven by application, dielectric sand core drying provides foundries with a means of achieving many of the desired goals.

Due to the nature of dielectric heating, the electronic sand core dryer transforms freshly-made green cores into completely dried cores in a matter of minutes. Cores come from the oven at low temperatures and can be used immediately in molds. Since heat energy is generated directly in the cores, rather than conventionally conducted from a heated surface, heat radiation into the core room is practically eliminated. Fumes and gases are exhausted from the oven through ducts to a point outside of the building. The elimination of heat and undesirable odors from the core room makes it a healthier and more pleasant place to work.

By extending the oven conveyor to the core bench, the coremaker can place green cores directly on the conveyor which moves them through the oven without additional handling. Dried cores may be removed from the outfeed table by the inspector and finisher ready to be delivered directly to the molding station. Consequent savings in equipment, labor and time cannot be overlooked.

This proven foundry production method has the support of binder manufacturers who have already developed binders that harden at a low temperature. They are confident that these new binders make possible better cores which, among other improved properties, have excellent collapsibility, excellent tensile and surface strength. As a result of these improved

ELECTRONIC SAND CORE dryer will revolutionize foundry operations. This streamlined dielectric oven and generator, with centralized controls, has an hourly production rate of 250 pounds of sand at three percent moisture. Unit approximates 64 sq. ft.

qualities, rejects due to blows, tears and shrinks are greatly reduced. In addition, dielectric heating offers control for these characteristics, actually guaranteeing uniform results.

Installation no problem

Commercially available sand core dryers emphasize low installation cost. This is possible because all equipment can be included in one or two major components. Essentially, however, the dielectric sand core dryer is made up of two parts, the generator and the drying oven. A schematic diagram of the equipment, with a sketch indicating the enclosed apparatus of each section, is shown in Figure 1.

The generator is a standard high frequency vacuum tube oscillator with proper transformers and rectifiers to produce r.f. power at about 10 mc (10,000,000 cycles per second). This power is piped to the dryer through the transmission line as indicated. The sand core dryer oven encloses the heating element consisting of an aluminum electrode with the base plate of the oven acting as the lower electrode. Also included in the oven are the conveyor, blower, and controls necessary to operate the unit.

Through proper design of electronic generating equipment, the standards are similar to those for other foundry production machinery. The vacuum tube oscillators are industrial air-cooled tubes giving long, efficient life without extra water connections. Minimum effort and auxiliary fixtures are required for installation. An a-c power outlet and a blower duct are the only external connections needed to operate the equipment.

The dielectric oven design provides the foundry with a simple and efficient means of producing more uniformly dried cores without emission of gases to the core room. One of its prime considerations was trouble-free operation. The electrodes, or heating area, consist of the base of the oven, made of stainless steel, and an aluminum electrode easily adjustable by means of a hand wheel located on the outside of the oven. Also controlled by the same hand wheel is the aperture for the exhaust blower. The electrode is matched to the generator by a shorted tuning stub which is operated by another hand wheel also located in a readily accessible position on the outside of the oven.

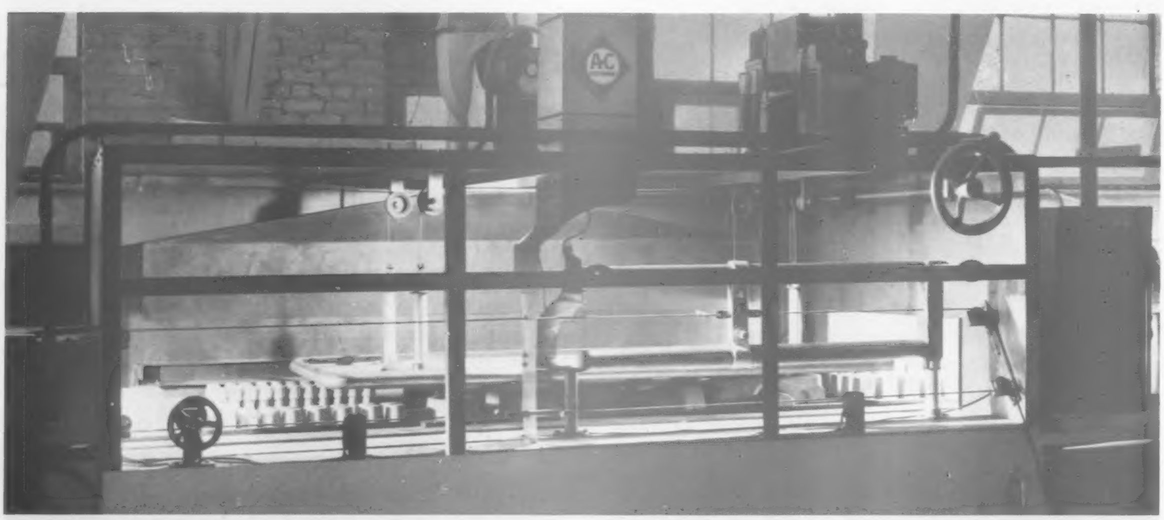
It is imperative that the steam and fumes liberated by the rapid heating of sand cores be drawn off without permitting the steam to be cooled below dew point. This is done by keeping the opening of the exhaust system on the same level as the under surface of the electrode. In this way a high velocity of exhaust can be obtained.

The conveyor, another integral part of the oven, consists of a hot material belt designed to have very little heating due to the dielectric field, and proper speed reduction and regulating devices to assure continuous control of belt speed.

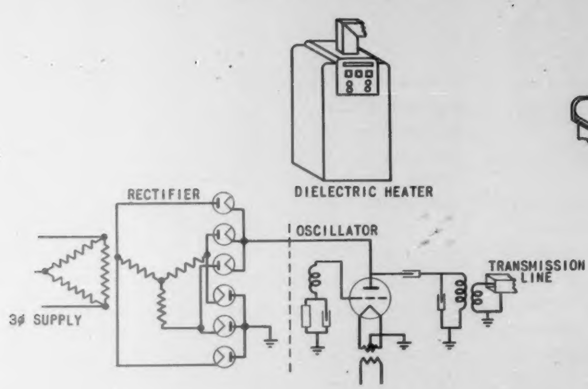
Necessary controls, minimized and simplified, are located at the exhaust end of the oven and consist of push-buttons and indicating lights for operating the blower, conveyor and RF power from the generator. Control hand wheels for the electrode height and tuning are also centrally located and easily accessible. The conveyor speed-adjusting wheel is found at the extreme lower end of the exhaust.

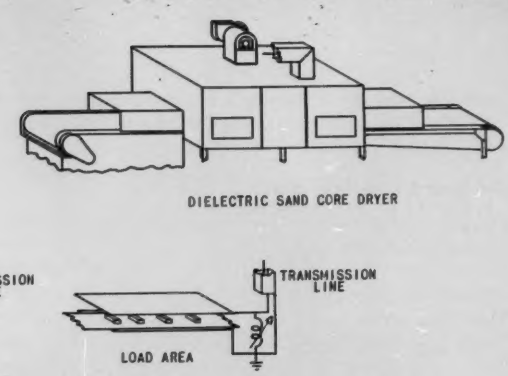
Old idea, new application

Theoretically, dielectric heating is a term referring to the extensive application of high frequency voltage gradient to some materials that have been commonly called insulators. The idea of dielectric heating itself is old, but it hasn't been until the last few years that equipment has been used extensively for this purpose. The heating element is the two electrodes which make up the capacitive portion of a resonant circuit. Work pieces are placed between these plates to become the dielectric of the capacitor. Heat is generated as a result of the rapidly reversing stresses to which this dielectric is subjected.



DIELECTRIC DRYING OVEN can dry cores of varying size and shape simultaneously without overbaking smaller or underbaking larger cores. The larger handwheel controls electrode and exhaust aperture height, while the smaller one tunes the oven to the generator. In production units, handwheels are located near the control panel, one above the other. Full output can be had in less than five minutes after unit is started.





PRINCIPAL ELECTRICAL components of the new sand core dryer are shown schematically. Simple design reduces operation to push-button control so that unit can be operated efficiently and economically by anyone. Oven and generator can be installed separately and connected by an overhead transmission line. Gases and fumes are exhausted from the oven and the generator to the outside.

Heating in the material is actually the amount of power absorbed and may be given by the following formula:

$$Pv = 1.41\, f\, E^2 e$$

where

Pv = power absorbed in watts per cubic inch

f = frequency in megacycles per second

E = voltage gradient in kilovolts per inch RMS

e = loss factor of dielectric material

The loss factor is the product of the power factor and the dielectric constant of the material.

In sand core terms, the loss factor is determined by the sand and the amount of moisture present so that in production, with green cores entering and dry cores emerging from the other end, the average loss factor is constant. The frequency used is predetermined by experimental work to obtain the best frequency for a particular drying operation. One variable remains—the voltage gradient appearing across the load. It is important, therefore, that voltage be as high as possible.

Because the characteristics of sand core change as it passes below the electrodes (result of the changing of loss factor due to the evaporation of water), the core becomes more difficult to heat. This problem was solved by the design of the electrodes. Because of the inductance of the electrode and by feeding the electrode at the end where wet cores enter, the voltage will increase across the electrode, giving a higher voltage whether or not cores are more difficult to heat. Because of this design much larger cores and those with considerably lower permeability may be dried by this equipment successfully.

The specifications for various cores used in the foundry vary with the type of casting. Variations include type of metal, kind of core and accepted practice. In many instances, castings using the same metal will differ from foundry to foundry. Consequently, there is no universal mix available to serve all purposes. But cores dried by dielectric heat have been used successfully for a variety of castings, such as gray iron, steel and non-ferrous metals.

Sand determines core quality

When speaking of the quality of sand cores, it should be understood that it is almost impossible to segregate the effects of the different types of binders and the use of dielectric heating. Binders which have been found suitable for use with dielectric heating ovens offer improvements over oil binders used in conventional ovens. Furthermore, these improved characteristics may be controlled and insured more readily with dielectric heating dryers than with conventional equipment.

Many of the sand core characteristics are controlled by the ingredients which make up the mix, and each of them, in some way, affects core quality. Production of a core is initiated by mixing sand, cereal binder, primary binder, and water. This mix is then rammed into the desired shape. The primary binder gives dry strength, be it liquid or dry. Each of these constituents contributes positive characteristics which are integrated in the production of the core and later manifest themselves in the finished product. Since the ingredients are as important as the mix, their properties are protected by testing and checking laboratories which measure the qualities of the materials individually as well as each mix for its specific function.

Sand is the body of the core and, more than any other ingredient, determines its quality. Core surface smoothness is generally determined by its grain size distribution of the sand, but may be modified by the addition of bentonite or silica flours. Grain size also affects permeability, although not as extensively as cereal and fillers. Grain shape and size, characteristic breakdown of sand and clay content determine the type of sand best suited for a particular core job.

Cereal binders are used primarily to add green strength to the core so that they will be able to support their own weight in the green state. Most of the primary binders used with dielectric core drying contain ingredients which give green strength to the core, thus reducing the cereal required. In many cases, rods and dryer trays are used to help give cores support in the green state. Rods are also used where addi-

tional dry strength is required. This is especially true where long, thin cross sections are subjected to great masses of metal when casting is poured.

Oil binders losing ground

Primary binders which give dry strength are numerous. Oil, of course, has been universally used for many years. However, development of the synthetic resin field has introduced a revolutionary idea into the foundry. Its possibilities are many. These neat resins, along with many compounded core binders containing them, are now available to foundries. Mineral binders are another product possessing good possibilities because of the quality of cores obtained and the absence of disagreeable gases or fumes in the pouring operation.

Special characteristics are obtained by compounding these binders. Better dry strength and additional green strength are the leading contributions of these special core binder mixes. As a result, there is also an appreciable reduction in the amount of cereal flours usually added in the mixing of the sand.

The core mixes used in steel foundries contain additional ingredients to give hot strength sufficient for the higher pouring temperature. Proper addition of fillers also results in desired shrinkage and collapsibility to keep the number of tears, blows and veining, resulting from casting higher temperature metals, at a minimum.

When these materials have been mulled together to produce a workable mix, cores may be manufactured for drying on the dielectric sand core dryer. Cores may be made on plates of Marinite, transite or plywood, or other materials and placed directly on the belt. The conveyor carries cores through the dryer which cures them completely so that when they emerge they are ready for the molder.

Push-buttons control the majority of operating functions. Manual operation is reduced to a minimum, with all of it related to preparatory adjustments. No special skill or training is required to adjust equipment; anyone can do it.

Since maximum efficiency is obtained when the space between the electrode and the sand core is kept at a minimum, the electrode should be adjusted so that the core will pass under the electrode within one inch of its surface. The conveyor speed should then be set to handle maximum loading of the belt.

Assume that that dryer is rated at 850 pounds per hour at the moisture contained in the sand. The core weighs 11 pounds and is placed on a 10-inch wide by 14-inch long core plate. If the cores can be made fast enough to load the belt completely, then the plates can be placed side by side, putting three plates on the 36-inch belt, with room left for loading and unloading. This means that the loading would equal 33 pounds for each 14 inches of belt, or 2.36 pounds per inch.

$$\text{Output} = 60\ LS$$

where output = pounds per hour at the moisture content of the mix

S = speed of conveyor in inches per minute

L = loading in pounds per inch

The factor 60 converts minutes to hours

Solving for S, $S = \dfrac{\text{output}}{60\ L}$

Substituting the above values, $S = \dfrac{850}{60 \times 2.36} = 6.01$ inches per minute

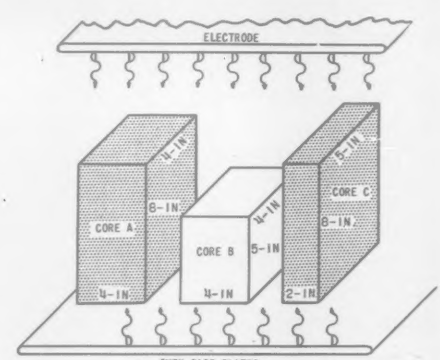
If, as these cores are run, the tuning adjustment is set so that the generator is fully loaded when the maximum loading is being used, then the load to the generator will vary so that the correct amount of power will be delivered to the electrode for the load. It should be kept in mind, however, that the loading is determined by the speed at which cores may be made. For instance, cores would have to be made at the rate of 1.29 per minute, or 46.5 seconds for each core. If the maximum rate was one per minute per core, then the production rate would be decreased to 660 pounds per hour.

Burning, over-baking eliminated

As previously stated, the amount of power absorbed from the generator is proportional to the loss factor of the sand core. Because of this, cores already dry can remain under the electrode without danger of burning or over-baking. This control makes it possible to run the equipment below full load and to vary the load.

Several sizes of cores can be run simultaneously through the dielectric sand core dryer. For example, in the sketch, core A is 4 inches by 4 inches by 8 inches high, core B is 4 inches by 4 inches by 5 inches high and core C measures 2 inches by 5 inches by 8 inches high; all are dried in one run. How do these varying sizes affect loading?

DRIED CORES EMERGING from the oven show the relation of the electrode height to the various sizes of cores. For best efficiency and power economy, the electrode should be not more than one inch above the highest core. Largest core shown weighs 21 pounds. Belt speed was set at 8 in./min.



VARIED CORE SIZE does not pose the same problem for dielectric ovens as it does for conventional methods. Cores in the sketch have varying masses and cross sections, yet all three can be dried successfully in one run.

FRESHLY-MADE CORES can be placed on the conveyor by the coremaker immediately after they are flopped from the core box to the plate. Because no intermediate handling is required, collecting racks between coremaker and ovens are eliminated.

Since the energy required to heat and dry the cores is proportional to the volume of A (reference core), then B will require ⅝ the energy needed by A. By the same token, C will also need ⅝ the energy of A. If the electrodes are adjusted so that the spacing is approximately nine inches, allowing space for core plates, then the load will tune into cores A and C more readily than into B. The reason for this is that the effective capacitance reflected into the circuit by each core is determined to a large extent by the air gap between the core and the electrodes. The capacitance of two condensers in series is equal to the product of the two over the sum. This is expressed as:

$$C_A \text{ eff} = \frac{C_A C_{XA}}{C_A + C_{XA}}$$

where

C_A = capacitance of core A

C_{XA} = capacitance of air gap for core A

Since C is inversely proportional to the thickness, then

$C_{XA} >> C_A$

therefore

$$C_{eff} = CA \frac{C_{XA}}{C_{XA}} \text{ or } C_A$$

The same is true for core C. That is, the effective capacitance reflected back into the circuit by core C is practically equal to its own capacitance.

A considerable difference arises in the case of core B. The air gap above core B is almost 3½ inches, compared to one half inch for cores A and C.

Thus

$$C_B \text{ eff} = \frac{C_B C_{XB}}{C_B + C_{XB}}$$

$C_B \text{ eff} < C_B$

Also

$C_B \text{ eff} < C_A \text{ eff}$

But when the effective capacitance of cores A and C are decreased until they reach the effective capacitance of core B, then core B will heat also.

Under these conditions, drying will occur in this order. Cores A and C will begin heating simultaneously, while core C will dry at a faster rate due to the smaller mass involved. Although core B will not absorb power as well as cores A or C, only ⅝ of the power is needed to dry it in the same total time.

Many advantages in new method

New processes and developments usually entail additional outlay for auxiliary equipment. In many instances, this may run into considerable amounts. Dielectric sand core baking provides a welcome exception in that the only supplementary equipment needed are trays. This is negligible because these can be produced cheaply by plastic firms.

Reduction of drying time from a matter of hours and days to minutes, faster production of better quality cores, gas, fume and dust-free atmosphere, elimination of cumbersome storage and cooling facilities, etc., are among the most prominent benefits to be derived from electronic sand core drying. Because of this latest development, any resemblance between yesterday's foundry and its modern version will be strictly accidental.

TWO 22,500-HP SYNCHRONOUS MOTOR stators being wound typify erecting floor hustle as shipments of equipment reach new highs. Six of these 13.6-kv, 180-rpm motors will pump Sacramento River water from the Tracy Pumping Plant near Oakland, Calif., through a 130-mile canal to the San Joaquin River at Mendota, part of the Central Valley Project. At no load, motors, under Regulex control, will operate as synchronous condensers. Oil pressure jacking of bearings will cut starting load.


RECLAMATION
0510 - 23201

SYSTEM TROUBLE! where?

Part Two of Two Parts

by W. E. SCHWARTZBURG
and R. P. HOLLAND
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Allis-Chalmers Mfg. Co.

Many alarm and annunciator systems are available, but simple, reliable schemes are still the best. Choose yours carefully.

OPERATION of actual annunciator circuits requires understanding of some of the common terms used in annunciator work. Basically, an annunciator is an electrical indicator wired to remote electrical contactors, such as push-buttons, which cause associated indications to appear on the indicator, thereby designating the locations of the operated contactors. Its purpose is to give a distinctive audible and visible alarm whenever trouble occurs. Usually, the audible alarm is given by a vibrating bell, horn or siren located on or near the switchboard. The annunciator itself should be centrally located within easy reach of the operator.

The annunciator panel can be made to consist of individual lamp annunciators or drops. The drop is defined as a visual electro-mechanical device with a target which is normally concealed, but which is revealed when the coil is energized by the contactor to which it is electrically wired. The lamp annunciator is one on which indications are illuminated by means of a lamp behind each window. Both types are commonly used and there are points pro and con for each type. Figure 5 is a photograph of a lamp annunciator, while Figure 6 shows a rectifier switchboard mounting a drop-type annunciator.

Immediate resetting essential

After the operator's attention has been gained by an audible alarm and he determines the cause of the trouble, the annunciator must be reset. This can be done manually, electrically, or automatically. Any annunciator in which resetting is accomplished mechanically and not by an electrical push-button is defined as manual reset. In this type each drop has one coil only. When the coil is energized, the drop target is released and falls by gravity into the indicating position. Indications are reset manually by means of a plunger or mechanical-action button to the non-indicating position. All manual reset annunciators are group reset; that is, all drops are placed in the non-indicating position at one time and not individually.

In an electrical reset type of annunciator, either drop or lamp type, the resetting is accomplished by pressing an electric push-button. Electrical reset annunciator drops and lamp annunciator relays each have two coils — one to "set" the indication, the other to "reset" it. The "set" coil, when energized, locks into indicating position. The "reset" coil, when energized, releases the lock and cancels the indication. Both operations are performed electrically.

The electrical reset annunciator can be group or individually reset. When reset individually, each drop or lamp is reset separately by push-buttons on the annunciator or at a remote point. As many reset buttons are required as there are indications on the annunciator. This can be seen in the annunciator shown in Figure 7 which has a switch below each lamp.

One of the advantages of the electrical reset drop and lamp type annunciators is that multiple operation is permitted. That is, two or more annunciators may be connected so that their indications, operated from the same contactors, set and reset in unison. This means that an alarm can be given in two remote positions simultaneously. The reason that a manually reset annunciator cannot be designed for multiple operation is that provision cannot be made for resetting together.

The automatic electric reset type of annunciator is not common since each new call resets the indication of the previous call and remains indicating until automatically reset

CENTRAL SWITCHBOARDS are the logical locations for annunciators. This duplex board has two lamp type annunciators on the right-hand panel, with instrument transfer switches mounted directly below them. Drop type annunciator on panel at left and circuit breaker switches equipped with red, white, and green lights provide additional system protection. (FIGURE 5)

ANNUNCIATOR PANEL mounted on a control switchboard with individual horn silencing and lamp resets. When trouble occurs, corresponding lamp lights and alarm sounds. Operator must reset switches individually. **(FIGURE 7)**

MERCURY ARC RECTIFIER station control has drop type annunciator mounted directly below the clock. The two indicators set directly above the recording instruments on end panels indicate tap positions of the two transformers. **(FIGURE 6)**

by the next call. This type of operation is not recommended as confusion usually results when one call follows another quickly, thereby cancelling the first indication. It is very difficult to know whether an indication has been taken care of properly.

Mechanical reset adds protection

Figure 8 is a diagram of the mechanical reset type relay, where, as previously stated, each drop has only one coil. Referring to Figure 8 if the fault contact closes because of trouble on a particular device or piece of apparatus, coil "C" and coil "H," which are connected in series, are energized causing the target to drop on both "C" and "H" relays. When the target on "C" relay drops to the position shown dotted it is visible to the operator; simultaneously the target on relay "H" drops and closes contact No. 2 and, consequently, sounds the alarm horn. Also, when relay "C" operates the contact, No. 1 opens and de-energizes the alarm bus. The horn may, therefore, be silenced by simply resetting the target on the common alarm relay.

It will be impossible to reset the individual drop relay if the fault contacts remain closed, thereby keeping a permanent indication that the trouble has not been cleared. It is possible to make this drop type annunciator electrically reset by the addition of solenoids.

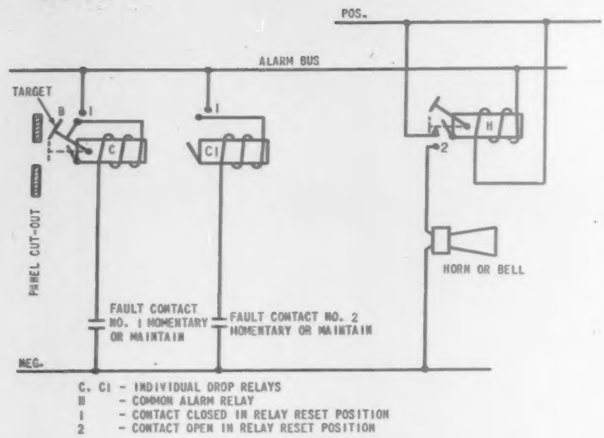
There is practically no limit to the number of point relays which can be used with one common alarm relay; however, it is advisable to provide two or more groups if the number of fault contacts become excessive. In this case a different alarm horn or ball should be provided.

The operation of the drop type annunciator is not limited to any particular voltage. It can be operated either on a-c or d-c power supply.

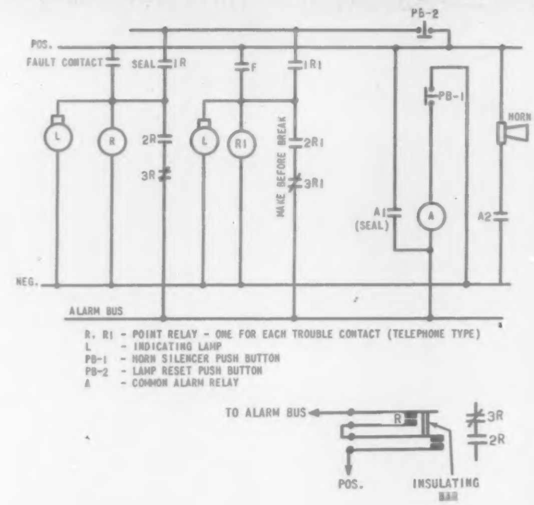
Another type of annunciator circuit is shown in Figure 9. This circuit employs a telephone type relay (Figure 9a) which has a "make" before "break" contact. This relay must have slow operating characteristics so that the time interval between the "make" contact and the "break" contact is great enough to allow the alarm relay "A" to pick up and "seal in" through its normal open contact. The particular advantage of this type of relay is that it uses very little space and, since either the "make" contact or the "break" contact must be open at all times, it precludes the possibility of "sneak" circuit feeding back into the relay when other fault contacts operate. To analyze the operation of this annunciator circuit it is necessary to examine the sequential operation of each device and relay.

Closing of the fault contact "F" when trouble occurs will energize relay "R." Since the fault contact may be momentary, i.e. overcurrent relay contacts, it will be necessary that relay "R" remain energized although the initiating contact opens again. This is accomplished by contact "1-R" which seals the coil of relay "R" through a normally closed contact of push-button "Pb-2" to the positive bus. Simultaneously, the lamp "L" lights and remains lit until such time as the operator releases the "R" relay by pushing push-button Pb-2. If the trouble has not cleared, the relay "R" will not reset and the light remains lit. When relay "R" becomes energized, contact "2R" closes and contact "3R" opens directly afterward, thereby giving an electrical impulse to the alarm bus of sufficient duration to allow the alarm relay "A" to pick up and seal itself in through its normally open contact "A-1" (seal). During the interval that alarm relay "A-1" is energized contact "A-2" is closed and the alarm horn is sounding.

To silence the alarm it is necessary to push push-button Pb-1 which will release alarm relay "A" and open contacts "A-1" and "A-2." Since the alarm bus has become de-



SCHEMATIC DIAGRAM of a drop type annunciator showing the physical operation of the individual drops. This relay performs all of the electrical functions of a good annunciator because it is sensitive to momentary as well as maintained fault contacts. Chief advantage of this scheme is that it is impossible to reset relay if fault persists. **(FIGURE 8)**



THIS ANNUNCIATOR embodies all electrical features in that all relays may be reset electrically without the use of mechanical devices. All relays and corresponding lamps can be tested simultaneously. Telephone relay shown at lower right shows the detailed mechanical arrangement of the "make" before "break" contact. **(FIGURES 9a and 9b)**

energized due to opening of contact "3R" the resetting of the alarm relay does not interfere in any way with the subsequent operation of the alarm when other trouble contacts operate.

Schemes should fit needs

The foregoing connections diagrams, Figures 8 and 9, show standard connections for commonly used annunciator and alarm schemes. However, exacting specification may call for special features in an annunciator that require special modifications. By reference and analysis of Figure 10 some of the advance features are incorporated.

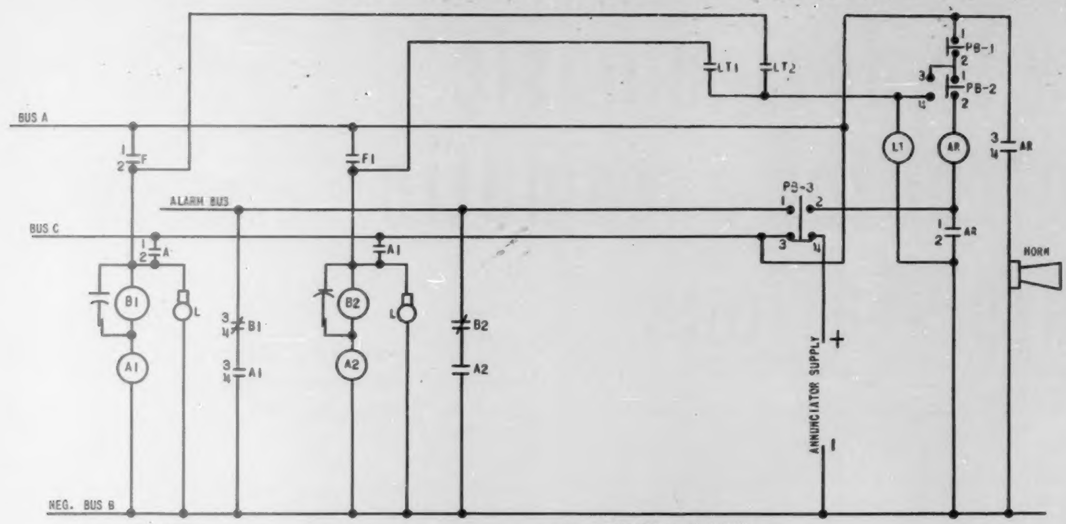
It will be noted that the impulse to the alarm bus is very positive and this is accomplished by use of a two coil relay "A" and "B"; a condenser is placed across the "B" coil to slow down the operation of opening of the normally closed contact of "B" relay.

The lights and relays may be tested by closing push-button Pb-2 without sounding the alarm horn.

Resetting of the lamps does not sound the alarm if trouble is existing or by the reverse operation of relay A-B, by operation of push-button Pb-2. The horn is silenced by pushing push-button Pb-1.

The following is a step by step analysis of the annunciator shown in Figure 10.

1. Contact F, 1-2 closes on trouble. This contact may be momentary or maintained and is usually located in a protective relay or at the trouble point, i.e., contacts on thermometer, float switch, pressure switch, etc. For simplicity, the annunciator supply power is d-c or positive and negative.
2. Since bus "A" is made positive through the normally closed contact of push-button Pb-3, contacts 3-4 and bus "B" are made constantly negative and the circuit is completed through the "A" and "B" coils of the point relays, thereby energizing coils "A" and "B," simultaneously.
3. Coil "A" will close its contacts 1-2 instantaneously, thus assuring that coils "A" and "B" remain energized (seal in) regardless of whether the fault contacts remain closed or the fault is of a momentary nature.
4. During the above procedure the actual operation of contacts associated with coil "B" is slowed up considerably by the action of the condenser, which parallels the "B" coil. Therefore, since the contacts of coil "A" are relatively fast in comparison to the contacts associated with coil "B," it follows that contacts 3-4 of coil "A" will be closed before contacts 3-4 of coil "B" have opened. This results in a negative impulse to the alarm bus, since contacts A, 3-4 and B, 3-4 are solidly connected to the negative bus "B."
5. Contacts 1-2 of coil "A" also will light the annunciator lamp.
6. During the interval that the "alarm bus" receives the impulse the relay "AR" (alarm relay) will become energized.
7. The alarm relay "AR" will remain energized, since it will seal in due to the operation of its own normally open contacts and through the normally closed contacts of push-button Pb-1, 1-2 and Pb-2, 1-2.
8. The normally open contacts 3-4 of the alarm relay AR will also remain closed to constantly energize the alarm horn to sound the alarm.
9. After the above operations have occurred the annunciator lamp is lighted and the horn is sounding.
10. To silence the horn regardless of how many faults have occurred it is only necessary to depress push-button Pb-1, which opens contacts 1-2 and de-energizes the alarm relay AR, which opens its contacts AR, 3-4 to de-energize the horn.
11. The lamp or lamps giving the visual indication will remain lighted to give a permanent record that trouble



F, F1 - FAULT CONTACTS
B1 - SLOW OPERATING TELEPHONE RELAY (ONE NORMALLY CLOSED CONTACT)
A1 - FAST OPERATING TELEPHONE RELAY (ONE NORMALLY OPEN CONTACT)
PB-1 - ALARM SILENCING PUSH BUTTON
PB-2 - LAMP AND RELAY TEST PUSH BUTTON
PB-3 - LAMP RESET PUSH BUTTON
LT - LAMP AND RELAY, TEST RELAY-MULTI-CONTACT
AR - ALARM RELAY (COMMON TO ALL POINTS) HIGH SPEED
L - INDICATING LAMP, VISUAL INDICATION

IDEAL ANNUNCIATOR schemes can be arranged. The line drawing illustrates a system which incorporates the advantages of the "make" before "break" contact together with special testing features needed in a good annunciator design. Positive action is obtained by using a two coil instead of a single coil relay, as shown in the sketch. **(FIGURE 10)**

exists or has occurred, since relay coils A and B are still energized.

12. If the trouble has cleared or has been corrected all lamps associated with this particular trouble may be darkened or reset by simply depressing push-button Pb-3 which opens contacts Pb-3, 3-4 which takes away positive supply to bus "C" and breaks the seal to the relay coils A and B.
13. If the trouble has not been corrected the relay coils A-B will not de-energize since their energization is maintained by the trouble contacts and, consequently, it will be impossible to reset the lamps on any point where troubles persist. This is a very desirable feature, since all lamps go out which are associated with troubles that have been corrected and all lamps remain lighted which are associated with troubles which persist, giving the operator a continuous record of all the points that are in trouble.

Occasional testing necessary

Since the annunciator is a device which plays an important part in the operation of mechanical or electrical equipment, some means must be provided for periodic testing of lights and relays connected with the annunciator. This is accomplished by simulating a fault condition for each annunciator position.

By reference to Figure 10, the relay identified on the diagram as "LT" is a multi-contact relay, that is, it must have as many contacts as there are lamps or fault points. The contacts are identified as LT-1, LT-2.

By pressing push-button Pb-2 contacts 3-4 are closed, thus supplying positive potential to all the relays and lamps. The horn is not sounded during this operation since the normally closed contacts 1-2 of Pb-2 are in the open position and, consequently, the alarm relay cannot receive the negative impulse it would normally receive due to the operation of the "A-B" relay.

Releasing of the Pb-2 will allow all the lamps and relays to remain energized, since they are all sealed in due to operation of their respective contacts A, 1-2. If any relay fails to pick up or is faulty, the lamp associated with these particular relays will not stay lighted. To reset all lamps after testing it is only necessary to depress push-button Pb-3 which opens contacts 3-4 and breaks the seal-in supply on all relay coils allowing them to reset to the normal de-energized position. During this operation it is also necessary to break the supply to all fault contacts, since if there happened to be a maintained fault contact closed during the time of testing all relays would pick up and it would be impossible to reset since bus "C" would be constantly positive through the maintained fault contact.

The number of horns or bells that can be operated from this annunciator is unlimited, that is, as many horns and bells can be located in as many locations as is necessary by simply allowing the contacts of the "AR" alarm relay to energize the operating coil of a master relay having a contact of sufficient capacity rating to sound the required number of horns.

Keep it simple

The alarm and annunciator scheme described in this and the previous installment is a simple, reliable, and field-tested arrangement. There are as many schemes as there are manufacturers; there is no such thing as one and only one system. Quick and reliable operation with a minimum number of relays are the most desirable characteristics of a good alarm and annunciator scheme.

In case of trouble, the alarm and annunciator system is the last barrier between successful operation and damaged equipment. Therefore, when new equipment is to be installed, the protective alarm and annunciator scheme should be given careful consideration.

how to design basic control for automatic hydro stations

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The job of laying out controls for small hydro stations that run themselves follows simple, fundamental principles.

RECENT YEARS have seen an increasing interest in completely automatic hydroelectric stations, to the point where they are quite common. There seems to be, however, quite a lot of confusion in regard to the best method of laying out the automatic control equipment for such a station. Much of this can be eliminated by a logical approach to the problem.

Modern hydro stations are designed for either full-automatic operation or for manual control, depending on the nature of the service. Full-automatic control refers to operation with no operator present, except for periodic maintenance work within the station, while manual control is defined as a type of operation of the station, which requires the help of an operator for starting and normal shutdown. Manual control also includes a type of operation sometimes classified as semi-automatic in which certain switching operations are handled automatically up to the point where the circuit breaker can be closed manually, connecting the generator to the transmission line and to the system.

The complexity of the problem involved in planning automatic hydro station control is reduced considerably if the designer's effort is directed into two distinctly different channels:

1. Safety
2. Sequence of operation

This division of the problem will considerably simplify the work necessary in designing circuits to provide safe operation of an automatic hydro station.

Considering safety first

Since safety for operating personnel and equipment must come first, it is obvious that safety rules and regulations should apply to a hydro generation station in the same way as with other types of generating stations of the same system voltage and capacity. The type and size of circuit breakers and associated primary protective relay equipment, therefore, is essentially the same as in any generating station, regardless of whether the operator is present at all times or only temporarily.

Safe operation from the point of view of the generator exists if current, voltage, and frequency are within the maximum and minimum operating limits. The turbine protection can be considered as a mechanical problem only. Overspeed protective devices supplement the operation of the governor. Automatic braking equipment is frequently designed right into the turbine controls, and where this is done the control circuits are made much simpler. Protection of the station personnel is assured through proper design of high tension switching equipment.

Thus relay equipment, whether installed for either machine or personnel protection, is essentially the same for fully automatic or for manual stations, with the exception of a timing relay called the "incomplete sequence relay." This relay shuts down the fully automatic station completely in case the automatic sequence switching operations are not carried to completion within a predetermined time.

The following list of protective relays covers the essential components needed for safeguarding the windings of a hydro station generator. All of these are operated from current and potential transformer sources. In addition to this a field failure is provided which shuts the station down in case excessively low field current prevails for any length of time.

Generator Differential Relays Protect machine winding.

Station Differential Relays For overall station protection.

Overcurrent Relays Prevent overloading of generator winding due to excessive current.

Temperature Relays Function on excessive generator winding temperature. (Two types of relays are available in this class: (a) direct acting temperature relay operated from a thermal element within the generator, (b) heater type temperature relay operated as a temperature indicating current sensitive device.)

Current Balance This relay is used to prevent station operation under excessive current unbalance of one phase against another. (This relay is of secondary importance and may be omitted for small generators without serious consequences if overcurrent relays for each phase are provided.)

Reverse Current Relay This relay prevents the motoring of the generator under adverse operating conditions and can be eliminated in a manually operated station.

Generator Overvoltage Relay This relay is used to make certain that the generator voltage regulator functions

properly and that the generator voltage does not exceed the phase limit.

Generator Undervoltage Relay This relay prevents operation under conditions of sustained low voltage and is able to detect conditions which lead to overload from transmission line faults.

The above list, of course, covers only the most essential primary protective relay equipment. All others have been eliminated for the sake of clarity. Other protective relays are not listed since they do not operate from an instrument transformer source. Thermal devices called "bearing relays" provide protection against turbine and generator bearing failure. In addition, an overspeed switch provides protection against excessive turbine speed. The contacts of all of these relays are connected in various ways into the station shutdown circuits, as will be explained later.

The speed with which machinery is destroyed under fault conditions makes it necessary that protective relaying be always designed on a full automatic basis. Figure 1 shows schematically in a single phase fashion the fundamental relay and switching equipment which is common for both types of hydro stations, full-automatic type and the semi-automatic or manually operated type. Since the prime purpose here is to outline the basic procedure in designing automatic hydro station control, all relays which are not absolutely essential have been eliminated from this description for the sake of clarity. In addition, bearing relays and overspeed devices have been omitted.

The simplicity of the protective relay scheme as shown in Figure 1 may seem surprising, but modifications to meet special requirements can easily be made. Therefore, synchronizing potential transformers, metering equipment, grounding relays and switches, etc., should be treated as strict additions to the fundamental scheme which remains simple and which presents no particular problem to anyone who is acquainted with the functions of the relay shown. The study of these relays can be simplified by reference to manufacturer's catalogs and relay application handbooks.*

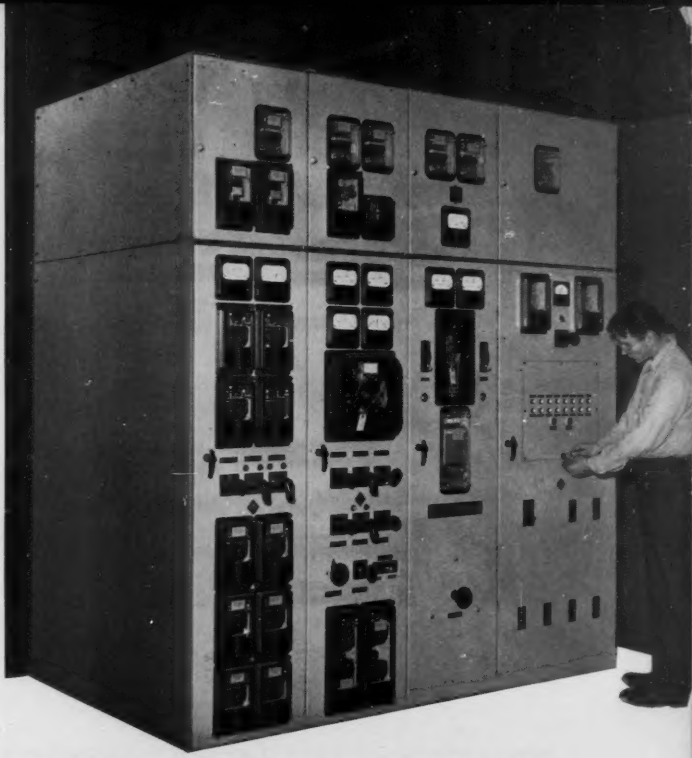
Preparing operation sequence

The means by which an automatic hydroelectric generator is placed in operation is standardized to a large degree and a measure of similarity in fundamental features can be found in most stations. This is not surprising since the basic elements which make up the hydroelectric station are seldom altered, and a strict sequence of events has to take place before the generator can be connected to the line. There are unimportant variations in the method of synchronizing the generator to an energized power line, but the effect upon general control principles is negligible. Therefore, the first approach to the problem is to prepare a list which gives the events for starting conditions in proper sequential order.

1. *Water*

Water must be present in sufficient quantity to justify the starting of the hydro station. A float switch in the forebay can be arranged to permit starting only if a predetermined water level is reached. This part of the control is called "head level control" and is largely standardized by manufacturers of hydraulic equipment.

* Copies of ASA Standards for Graphical Symbols and Device Numbers and Functions can be obtained by writing to the *Electrical Review.*



FIRST CUBICLE of typical hydro station control contains current transformers and current energized instruments and relays. Potential transformers and instruments and generator voltage regulator are housed in second cubicle. Third cubicle contains lightning arresters and automatic synchro-operator device. The fourth supplies control power.

2. *Control Power*

Since it is obvious that the station's function is based upon proper operation of all electrical control devices, it is of prime importance that a reliable source of control power be available at all times. The best solution to this problem is to provide a station type battery of approximately 125 volts d-c with an automatically controlled charger. Battery failure, however, is possible so a control power supervisory relay in the form of a d-c undervoltage relay is provided with its contacts arranged to prevent starting of the station unless proper control voltage is available. At the same time this relay is used to initiate immediate shutdown should the voltage of the control battery fall below 80 percent of rated voltage.

3. *Oil*

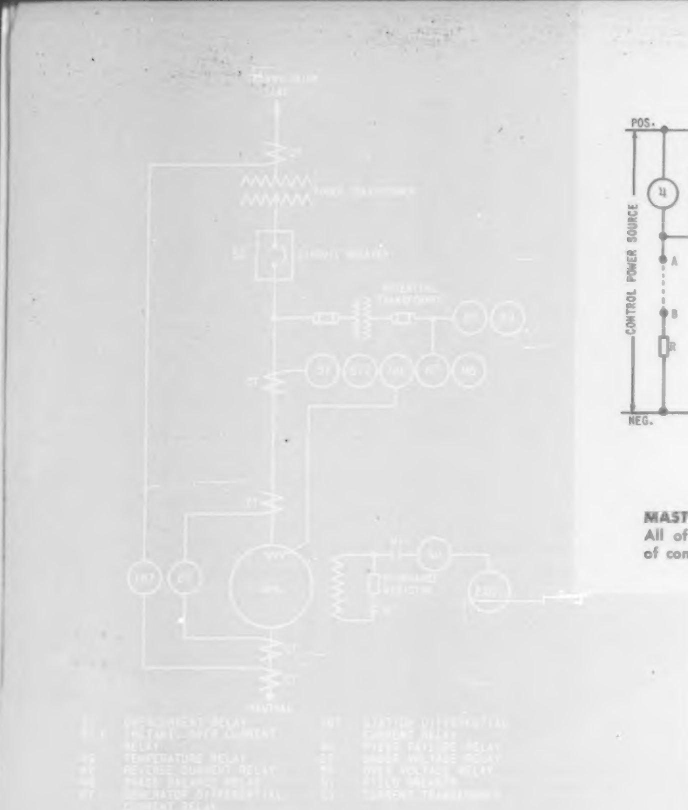
Oil under pressure is used for various purposes within a typical station. The governor will operate only if oil is available at a predetermined pressure level to operate the various pistons and gate-control devices. An oil pressure switch, therefore, is used to indicate whether pressure is up to the proper level.

4. *Cooling Medium*

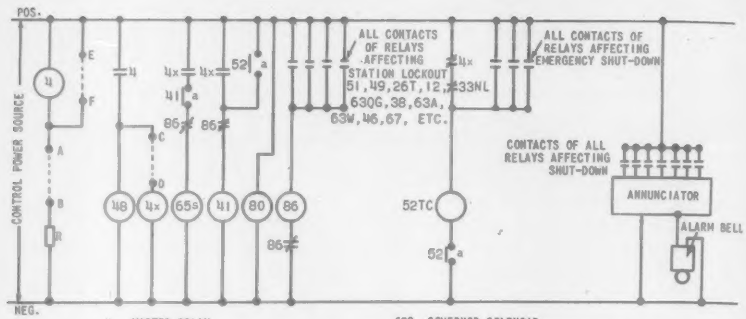
If artificial cooling is employed the same precautions apply as with oil. Where air or water is used an interlocking switch operated by the flow of the cooling medium prevents starting of the equipment unless adequate cooling is provided.

5. *Lockout*

The start of the station must be positively prevented if it has been shut down previously for any one of a number of internal faults such as insulation failure in the generator winding, or in the transformers, or station bus failure. In addition to this, the station must not be restarted if it has been previously shut down for any mechanical defects. For



SIMPLEST LAY-OUT of protective relays needed for automatic hydro station control is shown in this single-phase diagram. Relay numbering is based on ASA Standards No. C 37.2-1945[1] (FIGURE 1)



4 MASTER RELAY
4X MASTER CONTACTOR
41 FIELD BREAKER
48 INCOMPLETE SEQUENCE RELAY
65S GOVERNOR SOLENOID
52TC GENERATOR CIRCUIT BREAKER TRIP COIL
86 LOCKOUT RELAY
80 CONTROL VOLTAGE FAILURE RELAY

MASTER RELAY AND MASTER CONTACTOR arrangement simplifies control circuit planning. All of one class of controls are connected in series between points A and B. Other groups of controls are placed between points C and D and E and F. **(FIGURE 2)**

this to be accomplished, all protective relay devices which function when such faults occur are connected through a hand reset lockout relay which must be manually reset by an operator before starting can take place. At this point, of course, we rely upon the experience of the operator who should not reset this device until he has checked and removed the cause of the trouble.

6. *Master Element*

The master element (device 1) is defined as a device which gives an impulse locally or from a remote point to place equipment into operation, out of operation, or both, either immediately or after time delay. Such a device can be a voltage relay, power relay, power factor relay, float switch or any other device which functions at a time when the start of the hydro station is desired. The time of start can be delayed for any length of time by a timing relay controlled by the master element.

7. *The Master Relay and Master Contactor*

The master relay is the heart of the entire automatic control. The relay is controlled by all starting and stopping circuit elements and its position (energized or de-energized) is an indication of the state of operation of the entire automatically controlled station. The action of this important relay is supplemented by a master contactor. The master contactor is usually equipped with contacts of a higher current rating than a master relay because its duty is to energize devices with a greater current rating.

Master relay is heart of control

Figure 2 is a typical control circuit which shows quite clearly the advantages of the master relay and master contactor arrangement. As stated before, during the normal procedure of starting an automatic hydro station certain auxiliary devices have to be started before the water gates are opened and the turbine is started. The master contactor (or relay), therefore, is divided into two parts. Device 4 is a light duty relay under direct control of the master element described under Paragraph 6 above, and the master contactor (heavy duty relay) or contactor (device 4X) which is indirectly controlled by the master element through the function of device 4 and various other devices to be explained later.

Arrangement of contacts is as follows:

Between points A and B, in Figure 2, all contacts of devices are located which are closed if starting is desired or required such as water level (Paragraph 1), lockout relay in operating position (Paragraph 5), master element (device 1, Paragraph 6), and other devices such as safety interlocks, etc., which have to be decided upon in each individual case.

Thus the master relay is placed under the influence of all devices which call for a start of the station and, if all such devices are in accord, the circuit between points A and B will be closed and the master relay, device 4, will be energized. At the same time a timing relay, device 48, is energized through one of the contacts of the master relay. This relay is set for a fixed time after which its contact will give a signal and effect shutdown and lockout unless the starting cycle has been successfully completed within the predetermined time. This relay is of extreme importance for an automatic station since, in a way, it replaces the operator. It may be equipped with more than one contact in order to check proper operation of intermediate control elements during the starting cycle.

The contacts of master relay 4 are arranged to energize all auxiliary devices which are necessary for proper operation of the station such as oil pressure pump (Paragraph 3, above), cooling fan (Paragraph 4), etc. If all devices are in proper operation the circuit between points C and D will be closed and master contactor 4X will be energized. The contacts of this device are connected to the water gate solenoid, field breaker

closing coil, etc. The energizing of the master contactor 4X will mark the instant at which the turbine and generator start to rotate. This marks the end of the second step in the process of starting the hydro station. It will be realized that so far only straightforward sequence control was in question.

Quantitative adjustments follow

We are now at that part of the control cycle which deals with quantitative adjustments of certain devices. In order to synchronize the generator with the transmission line or station bus devices must be provided to make automatically quantitative adjustment of:

A. Turbine speed by means of the governor.

B. Generator terminal voltage by means of the voltage regulator.

C. Automatic adjustment of angular generator voltage velocity and automatic adjustment of the phase angle between generator voltage and line voltage.

D. Automatic loading of the turbine and generator.

Steps A to D deal with control elements which have to be properly designed to meet the turbine, generator, and system characteristics. The proper application of these devices requires that the engineer obtain information about the design details of the turbine and governor to be used. He will have to study the generator and exciter characteristics to determine the operating range of a particular type of voltage regulator. He will have to decide upon the type of synchronizing devices to be used and will have to be careful not to overlook unusual operating situations, for instance, extraordinarily low voltage conditions or instability of frequency in a power line which is to be picked up by the incoming generator. He also will have to study all conditions under which the generator is to carry load.

The problems involving the turbine governor are normally taken care of by the manufacturer of the governor, and it is necessary only for the control engineer to check if all auxiliary devices which are needed for proper automatic operation have been ordered and supplied with the governor. To properly fit the governor into the picture of an automatic hydro station one has to think merely of a device which will regulate frequency in a predetermined manner, and the process of taking up load and reducing it is entirely associated with automatic adjustment of the governor speeder spring.

Referring to step B, the voltage regulator is usually preset for a given voltage level and requires no further attention. Step C is necessary because the governor alone, as a frequency controlling device, is not capable of synchronizing a generator with a power line except in cases where the generator breaker and field breaker are closed at the same time as the generator is pulled "into step" by sheer force and with resultant voltage disturbance. In automatically operated stations (and preferably in manual stations also) it is therefore necessary to assist the governor with a device which will be sensitive to the differential in turbine speed (generator terminal frequency), transmission line frequency, and phase angle difference between generator voltage and transmission line voltage. This device is called an automatic synchronizing relay.

Step D provides the automatic loading where the governor is not equipped with automatic load proportioning devices.

Figure 3 (a and b) shows the electrical connections to provide Steps A, B, C, and D. The sequence of operation of control apparatus is as follows:

As soon as the generator has developed sufficient voltage to pick up the auxiliary synchronizing relay device 18 (usually set for 80% normal voltage) the synchronizing relay device 25 is connected across two potential sources, the generator potential transformers, and the line or bus potential transformers. The automatic synchronizing relay is of such construction that it is able to compare two voltages to their respective angular velocity and ultimate phase angle. A study of the detail parts of a water wheel governor will reveal the fact that usually a split field motor called "synchronizing motor" (device 65MS, Figure 3) is used to make adjustments on the speeder spring of the governor. The result of such changes is a variation in turbine speed. During the process of synchronizing, this governor motor (65MS) receives electrical impulses by means of closing and opening contacts marked in Figure 3, 25R and 25L. The closing of contact 25R will raise the turbine speed while the closing of 25L will lower it. A third contact (25C) of the synchronizing relay closes the generator circuit breaker device "52" at the instant synchronism has been established.

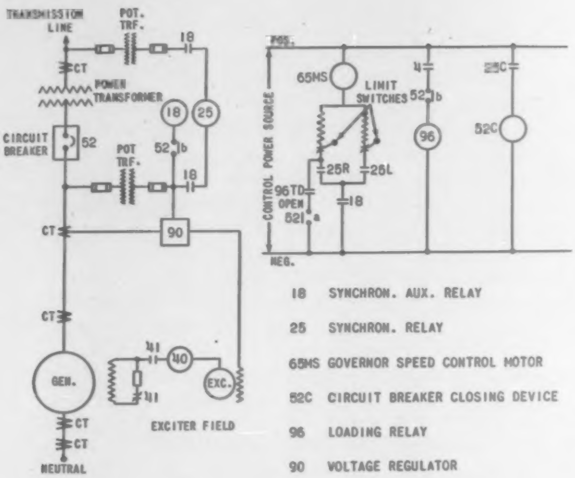
The voltage regulator is connected to the generator potential transformers and to a compensating current transformer in case more than one generator is operated on the same station bus. The voltage regulator acts upon the exciter field current in a manner which is well known and which offers no problem to the control engineer.

Load controls take over

After synchronism is established and the circuit breaker "52" has closed the following requirements exist:

1. The automatic synchronizing relay should be disconnected.
2. The voltage regulator may be disconnected if a relatively small generator is operated in connection with a system of high stability. In this case the generator is operated with a predetermined fixed excitation after synchronism has been established.
3. The governor motor must be influenced to make adjustments on the governor which in turn will influence the turbine to assume a predetermined amount of load. One method is shown in Figure 3 employing a so-called loading relay device 96. This relay is an instantaneous pickup and adjustable drop-out time delay relay of the flux type. The contact of this relay is used to raise the setting of the speeder spring on the governor in order to take up load after synchronizing. If the governor is not equipped with a load limit adjusting motor operating upon a load limiting device on the speeder rod, then the loading relay provides a means for taking up more or less load, depending upon its time setting. Governors also can be equipped with the so-called head level control mechanism which will automatically and on a purely mechanical basis adjust the governor in such a way as to proportion the turbine load in relation to the available water head.

The designer of control circuits therefore has to be acquainted with the features with which the governor of a specific installation is equipped. The need for one or the other of such features is open for discussion, but a general statement may be in order: Operations such as automatic loading, automatic load proportioning (head level control), and automatic braking are best accomplished through mechanical



QUANTITATIVE ADJUSTMENTS that must be made before generator can be synchronized with the line are made through operation of devices shown in the diagram. Heart of this operation is the automatic synchronizing relay, device 18, shown in the diagram. **(FIGURES 3a and 3b)**

FULLY AUTOMATIC CONTROL for a 3,000-kva, 2,400-volt, 60-cycle hydro-electric station will be provided by this indoor switchgear assembly. A 50,000-kva vertical lift circuit breaker is contained in the cubicle at left. Annunciator panel lights indicate operation of various relays.

devices directly connected to the turbine governor. Since any simplification in the electrical control scheme is generally considered as reducing the possibility for failure it will be found desirable to use as many mechanical control devices as possible, carefully comparing their cost against electrical devices which accomplish the same thing.

This concludes the study of that part of the automatic control scheme which deals with the starting of the station.

Shutdown procedure can be simplified

As previously explained, master relay 4 and master contactor device 4X are the control elements which start the hydro unit, and it is obvious that they can be used for shutdown provided connections are arranged similar to those as shown in Figure 2. At this point the circuit designer should realize the advantages of a centralized control in which all functions of separate control devices are summarized and interpreted by only two devices, namely: the master relay, its positions being identical with the *intention* to start and stop the station; and the master contactor, the device which *executes* the command of the master relay provided it is safe to do so. Considerable simplification and flexibility of the entire control scheme is achieved if the circuit layout is kept consistent with the purpose of the master control devices as described.

Differentiation between a "normal" and an "emergency" shutdown is desirable, depending upon the seriousness of reasons and the nature of the fault. During a *normal* shutdown, the water gate is closed first to the "no load" position at which point the generator circuit breaker opens automatically through the action of a gate limit switch which closes its contact at the moment the gate is passing through the no load position. Under *emergency* shutdown conditions the circuit breaker and field breaker are simultaneously tripped as fast as possible regardless of the position of the water gate. As a result, normal shutdown is associated with a gradual transfer of power from the hydro generator in question to other sources of power which are connected to the system. Under emergency shutdown conditions, the power flow from the hydro generator into the system is abruptly stopped. This will cause the water turbine to overspeed and will also result in disturbances in the power distribution within the transmission line.

Normal or emergency shutdown may also be associated with station lockout, depending upon the availability of an operator. Here, of course, we are only considering the design of an entirely unattended station. The methods of shutdown and lockout are principally affected by the degree to which automatic operation is carried. The master element previously described as device 4 can be replaced by a control switch in semi-automatic stations, so that fault conditions can be taken care of by the operator.

Four shutdown conditions open

In an unattended station the general list of shutdown conditions follow. For each condition the operation of control relays is analyzed with reference to Figures 2 and 3. For a normal shutdown, the control relay operation is as follows:

The circuit of the master relay "4" is opened by the devices listed below. These devices have their contacts in series as part of the circuit between points A and B.

1. *Normal Shutdown, Automatic Restart*

   Automatic head level control device.

   Load sensitive relays such as underpower relays, etc.

Timing relays which start and stop the station at a predetermined time.

All voltage relays, power factor relays, etc., which are classified as master elements device 1.

Master contactor "4X" and governor solenoid "65S" are then de-energized.

The turbine gate will close to the "no load" position and limit switch device "33NL" causes the circuit breaker "52" to open. If conditions are favorable, station is restarted automatically.

2. *Normal Shutdown and Lockout*

In this type of operation lockout relay 86 is operated in addition to master relay device 4 and master contactor 4X. This effect is a result of the operation of relays typified by the following:

Moderate overload as indicated by the induction element of an overload relay device "51."

High generator temperature as indicated by the temperature relay device "49."

High transformer temperature which actuates device "26T."

Turbine overspeed which closes the overspeed switch device "12."

Governor oil pressure failure which operates oil pressure switch device "63QG."

Bearing oil pressure failure which closes the contacts of device "38."

Cooling air or water failure which closes contact "63A" or "63W."

Phase current unbalance relay device "46."

Reverse current as indicated by the operation of device "67."

Under these conditions, master relay device 4 is de-energized by interrupting the circuit between points A and B or short circuiting the relay coil between points E and F. The master contactor 4X is de-energized by interrupting the circuit between points C and D in both cases through the action of a lockout relay called device 86. Contact 33NL will then trip circuit breaker "52" in the no load gate position as previously described in a normal shutdown.

3. *Emergency Shutdown, Automatic Restart*

This condition is characterized by the operation of an instantaneous overcurrent relay device 51I which is usually combined with an induction overcurrent relay as described under "normal shutdown and lockout." An excessive overload due to line fault will operate this instantaneous overload relay. Severe line undervoltage is usually associated with a line fault. This will also cause the undervoltage relay device "27" to operate.

The control relay operation is such that the circuit breaker is directly tripped by the instantaneous overcurrent relay. At the same time the circuit of the master relay 4 is opened by a contact in the undervoltage relay device "27." Master contactor 4X will also be tripped. This shuts down the water turbine through action of the governor solenoid 65S. Upon return of voltage the synchronizing relay device 25 will immediately put the stations back into service after normal system voltage has returned and after synchronization has taken place.

4. *Emergency Shutdown and Lockout*

The most severe fault condition in the station is characterized by operation of the following relays:

Generator differential relay device "87" indicating generator winding failure.

Overall station differential relay operation device "187."

Control voltage failure device "80."

Generator overvoltage device "59."

Generator field failure device "40."

In this case the control relay operation is such that the lockout relay device "86" is energized by any one of the above relays simultaneously opening the connection between A and B of the master relay. The circuit breaker is opened at the same time by another set of contacts of the same relay or indirectly by an auxiliary tripping relay. Summarizing then, in an emergency shutdown and lockout, the circuit between points A and B is opened (or circuit between points E and F is closed), lockout relay 86 is tripped and the main breaker is opened.

Many control variations are possible

The fundamental control elements of a full automatic hydro station are readily adaptable to stations with various degrees of automatic operation. One of the most common variations is used in the many stations which are started and stopped from a remote point by means of a control switch. A starting relay energized by contacts of the control switch replaces the master relay (master element device 1) in such cases. From this point on, all other control operations are carried out on a full automatic basis so it is unnecessary to give this type of operation special consideration. If other functions, besides starting and stopping, are to be accomplished within the hydro station from a remote point, complete supervisory control design must be considered. This type of control equipment falls beyond the scope of this article and stands in a class of its own, deserving to be treated accordingly.

Annunciators are widely used in hydro station control to indicate the cause of trouble and to identify that part of the equipment which was responsible for a shutdown. From the control engineer's view, all annunciators can be treated more or less as simple boxes equipped with a series of terminals, the number of which is identical to the number of devices which are introduced into the general control scheme for the purpose of shutdown under fault conditions. The important feature of an annunciator to be used in an automatic hydro station is its ability to record the source of trouble and to maintain this record until an operator responds to the alarm call. This record should be maintained until such time as the operator has a chance to investigate and manually reset the annunciator.

It is advisable that a full automatic station be equipped with an operation counter connected in parallel with the coil of the master relay. This arrangement will enable the operator to make necessary adjustments in case an excessive number of starts and stops have taken place within a given period of time.

The fundamentals of an efficient sequence control are simple and offer no special problems, provided the designer approaches this matter in proper sequential order breaking down a complex series of operations into a series of simple functions. In this manner the designer can incorporate the best of modern control practice in safety, efficiency, and economy in any automatic station whether the capacity be large or small.

CARE OF AC ROTATING EQUIPMENT

Part Four of Four Parts

by **FRASER JEFFREY**
Assistant to the Chief Electrical Engineer
Allis-Chalmers Mfg. Co.

Familiarity with construction, operation and limits of machines is the most practical guarantee for efficient operation.

MAINTENANCE prolongs the productive life of a machine by giving it those considerations which keep it at its best operating efficiency. Frequency and type of maintenance are determined by the nature, construction, application, and location of the equipment. Repair, as pointed out in previous installments, is an extension of machine upkeep in that it remedies breakdowns and failures which ordinary care could not prevent or which were caused by neglect, ignorance or wearing out of parts.

As stated before, a correct diagnosis of the reasons and cause of machine failure oftentimes leads to more effective and permanent maintenance measures. Perhaps the difficulties may not be a maintenance problem at all and the corrective measure might lie entirely outside of the machine itself. Many of these special problems, or hidden things, could extend machine life and efficiency considerably if fully understood and properly applied.

Banding armatures and other rotating equipment

One of these special considerations is the banding of armatures and slip ring induction motor rotors. There is a definite reason why this banding is sectionalized. On slip ring induction motors used to accelerate heavy loads over a fairly long period of time or that perform their starting function frequently, a band on the rotor, if not properly sectionalized or of the proper material, oftentimes will have enough heat generated in it, due to the large stray flux field set up, to melt the solder from the band. Where stress conditions allow, the band wire used should be made of non-magnetic phosphor bronze material to minimize heat losses when starting. If stress conditions do not permit such usage, then austenitic steel must be used. Ordinary steel band wire may be used where no limitations exist.

Considerable care must be taken when bands are replaced. The type of material, band sectionalizing, as well as the pull or drag on the wire during banding, must be watched. The various materials have specific strengths, as indicated:

1. Steel band wire—tensile strength of 210,000 psi,
2. Austenitic non-magnetic band wire—tensile strength of 210,000 psi,
3. Phosphor bronze non-magnetic band wire—tensile strength of 120,000 psi.

All band wire should be tinned to facilitate soldering and must be strong enough to be bent through 180 degrees flat upon itself without breaking.

If the drag on the band wire is not under control when it is being applied, the wire might be stretched beyond its yield point. This may show up ultimately during operation as a defect causing failure and loss of production.

The correct degree of tension must be applied uniformly to the band. Figure 13 shows a device commonly used to obtain uniform and accurate wire tension. Its component parts can be obtained easily on location for any banding job. The device consists of a piece of timber, pipe or light I-beam, one end of which supports a standard steel drum, such as an oil barrel, and the other end a sheave of at least ten inches in diameter.

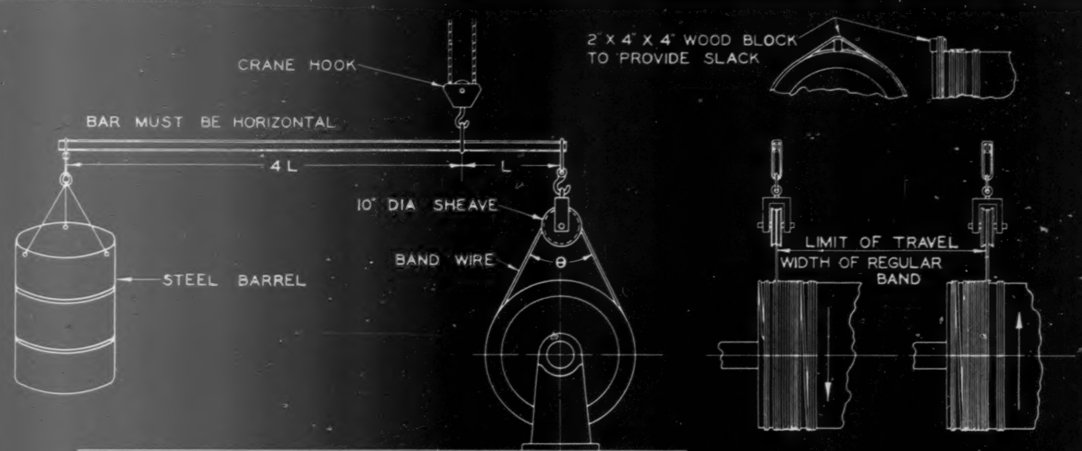
The beam is suspended from a crane hook, chain hoist, or block and tackle at a point one-fifth of the span from the sheave end. A beam ten feet in length is commonly used with the point of suspension two feet from the sheave support and eight feet from the barrel support. Water is added to the barrel to obtain the required loading. Loadings given in the table of Figure 13 represent the total safe load required at the end of the beam, including weight of barrel, weight of water in barrel and one-third of the beam weight. The requirements cover various kinds of band wire, with a good margin added for safety.

The starting end of the band is anchored by attaching a cord, which has been wound around the rotor, to a hook bent in the end of the wire and by crossing the second turn a number of times over the first. The first two turns may be soldered. Three or four extra turns are added at each end of the regular band. Adjacent turns of the regular band should touch, but the extra turns are set off a half-inch or more. Where the extra turns run off the band insulation, the coils should be protected by placing a .040-inch fuller board under the band wire.

Both ends of a rotor may be banded in one continuous operation. The wire is run on the rotor with just enough tension to hold it in place. At the end of the band, three turns are run over a 2-inch by 4-inch by about 4-inch long wood block laid on edge, which can be removed to pick up slack in the wire. The final end of the band wire is soldered to the adjacent turn and to a clip.

Remove slack, apply solder

The wood block is removed after the band wire has been wound around the rotor. The slack thus provided is used to pass the wire over the sheave while the barrel is resting on the floor



Wt. of Water — $8\frac{1}{3}$ Lb. Per Gallon.

Total Load at End of Beam Including Weight of Barrel and 1/3 Weight of Beam.																	
Band Wire			Steel							Phosphor Bronze							
			Tension in Wire		Load On Beam — Lb.					Tension in Wire		Load On Beams — Lb.					
B. & S. Gage	Dia. In.	Area Sq. In.	Force Lb.	Stress Lb./Sq. In.	Angle θ of Wire Over Sheave 0°	30°	60°	90°	120°	Force Lb.	Stress Lb./Sq. In.	Angle θ of Wire Over Sheave 0°	30°	60°	90°	120°
8	.1285	.01295	850	66,000	425	410	368	300	212	600	46,000	300	290	260	212	150
10	.1019	.00817	600	73,500	300	290	260	212	150	400	49,000	200	193	173	141	100
12	.0808	.00512	400	78,000	200	193	173	141	100	250	49,000	112	108	97	79	56
14	.0641	.00322	250	78,000	125	121	108	88	63	160	50,000	80	77	69	56	40
16	.0508	.00203	160	78,000	80	77	69	57	40	100	50,000	50	48	43	35	25

REQUIREMENTS FOR BANDING armatures of d-c machines and rotors of slip ring induction motors can be met easily by any concern set up to maintain and service such equipment. Usually, materials needed can be obtained from regular company supplies, since no special or expensive apparatus is required. Line drawings of banding device, procedure and water loading needs for each type of band used are shown above. **(FIG. 13)**

or on blocks. The tension device is lifted by the crane so that the beam is approximately horizontal with the barrel suspended free of other support. The included angle of the wire over the sheave is estimated and loading is adjusted accordingly. The armature is slowly turned to run the sheave back to the starting point. This process is repeated, raising the tension device as slack is removed from the wire so that the beam remains approximately horizontal. If the angle of the wire over the sheave changes appreciably, weight must be added to correct the loading. The sheave should not be run into the extra turns provided at either end of the regular band. To do so may cause the temporary fastening of the wire to give way.

When no further slack can be taken up, the sheave is stopped just outside the regular band, and the band clips are bent over and soldered at each end of the band. Tension is thus relieved, and the surplus turns of wire are cut off and removed. The balance of the clips can then be crimped over the band and the entire band soldered.

Best results are obtained by heating the coils before banding to make the insulation more flexible so that the coils can be pressed into place more easily and uniformly. The rotor may be heated either in an oven or by internal circulating current until a uniform temperature of approximately 85 degrees C is obtained throughout. The band is then applied while the coils are hot.

Temporary banding may not always be necessary except in those cases where the coils must be pressed to an unusual extent, or when the rotor is of the high speed type where centrifugal action causes sufficiently high pressure on the insulation to further compress it to the extent that the band may become loose after considerable operation.

Expansion and contraction effects dangerous

Another important but often overlooked fact is that copper in the winding or coils of rotating electrical machines has a relatively high coefficient of expansion. Every time a machine starts up from a cold condition to a loaded hot condition the copper in the windings expands. The iron in the core sections also expands, but not to nearly as great an extent as the copper, so that the "difference" in expansion of the two materials causes an actual slipping of the copper in the winding over that of the insulation on the winding and of the coil insulation itself on the iron portions of the core. While this is a condition associated generally with long core, high capacity machines, such as turbo-generators, the solution of the problem lies largely in the methods of operation that will tend to keep these machines at a more or less constant temperature, either when

MIXTURE			BECOMES PLASTIC AT	BECOMES FULLY LIQUID AT
45% Tin	55% Lead	——	181°C	221°C
50% Tin	50% Lead	——	177°C	220°C
66% Tin	34% Lead	——	182°C	——
*100% Tin	——	——	232°C	232°C
95.45% Tin	3.28% Copper	1.07% Antimony	231°C	254°C
2.50% Silver	97.25% Lead	.25% Copper	296°C	302°C

* There is no difference between the plastic and the fully liquid points. Soldering with pure tin may require special technique in order to make the solder hold tight.

TABLE OF MIXTURES and temperature properties of the more commonly used solders indicates by their differences that they are meant for some particular application. The type of solder selected is determined by the operating conditions of machines on which it is to be used. **(FIGURE 14)**

shut down or when operating under load. This has resulted in the frequent use of turning gears so that the machine, when shut down, is rotated at relatively low speed by a motor geared to the shaft of the large machine.

Another practice is to preheat the machine before bringing it up to full speed. This is done because a large part of the total length of the field copper in the larger and longer core types of turbo-generators may be clamped to the rotor slot wedges due to the high radial forces caused by centrifugal loading. If the rotor copper in these long core machines is heated while in this clamped condition, the stresses due to expansion may become sufficiently great to deform it. The more frequently this cycle of heating and cooling occurs, the more pronounced the deformation becomes. Ultimately it may result in overlapping of the rotor copper conductors on the ends of the rotor core until the copper breaks, or short circuits develop between turns.

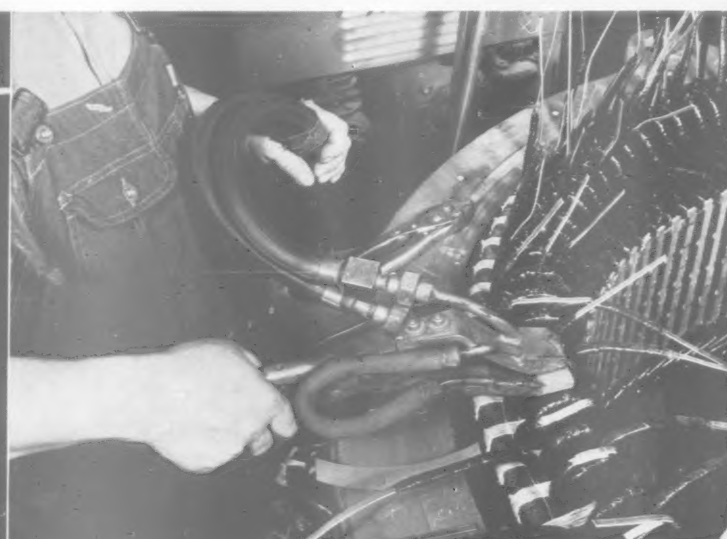
These tendencies can be minimized by using turning gears or maintaining the machine at as nearly constant temperature as possible, whether the equipment is shut down or operating. This practice is becoming more generally used. Its spreading acceptance also indicates that definite practices will be established in time for methods of operating such equipment. It is obvious, therefore, that the effects of temperature are not always confined to the life of insulation from the standpoint of temperature only.

Watch operating temperatures of equipment

Temperatures indicate whether or not a machine is operating properly. This matter of temperature and temperature rise should not be taken as a matter of course because it demands considerable skill in arriving at reliable results.

Locations of thermometers on the ends of the stator coils may record temperatures entirely different from those located in the vent ducts of machines. Readings may also be quite different from results obtained by embedded temperature detectors located between the upper and lower coil sections in the middle of the core of any given machine. When only bulb thermometers are available, it is advisable to use at least six or eight of them located in various sections of the core, vents and coils. Large generators, such as steam turbine driven units, are usually built with embedded temperature detectors set in the slot portions of the core between the upper and lower coil sides.

Increasing temperature rises for the same load conditions are an indication that something may be wrong. Possibly the



ELECTRICAL BRAZING of rotor bars to the end rings of a squirrel-cage induction motor rotor, using a high melting point silver content solder, produces an indestructible joint from the standpoint of any temperature that might be encountered even under the most severe service conditions. **(FIGURE 15)**

HIGH MELTING POINT solder containing silver is used to braze stator winding series leads to obtain a joint which will withstand high temperatures and vibrations sometimes encountered under unusual service conditions. Such brazing is faster, more economical and more efficient than previously used practices. **(FIG. 16)**

machine may be becoming clogged with dirt and dust; if it has a closed system of ventilation, perhaps the screens are becoming dirty, thus cutting down the flow of air, or something may have happened to the flow of water to the coolers, etc. Therefore, the proper interpretation of temperature rise, as well as the total temperature, is a barometer of safe operation that is most important from the standpoint of service continuity.

Solders differ in type and use

Soldering and solders are commonplace things frequently overlooked because both the process and the materials are used universally in shops and homes. To some people solder is solder, but to the discriminating minority there are tremendous differences in solders, many of which are used for special purposes over wide ranges of temperatures.

Some solders are used for high operating temperatures, some for their greater mechanical bonding abilities, etc. Many of these solders usually require different methods of application or handling. A few of the more widely known solders and their approximate properties are shown in Figure 14. There are also various silver solders with various mixtures of silver, copper and zinc, with plastic points varying from 600 degrees C to 750 degrees C.

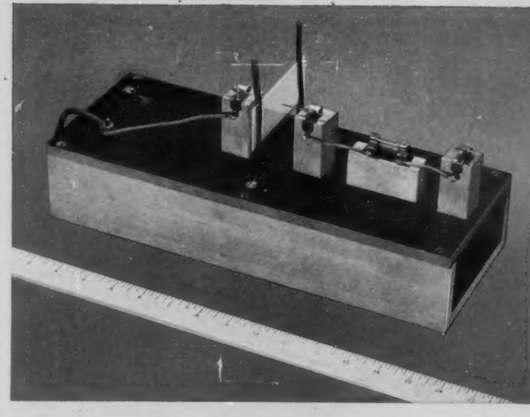
The use of silver solders has been extended considerably by high frequency electronic heating and special brazing machines where the temperature is obtained by shorting the joint to be made between the two jaws of the machine, Figure 15. In this particular illustration, the machine is brazing bars to the end rings of a squirrel cage induction motor with a thin piece of high melting point silver solder interposed between the bar and the end ring. Figure 16 shows the series leads of a stator winding being silver brazed by a hand tongs method.

Therefore, each and every type of solder considered must have its application dependent on the structural parts to be soldered and the future service conditions to which it is to be subjected.

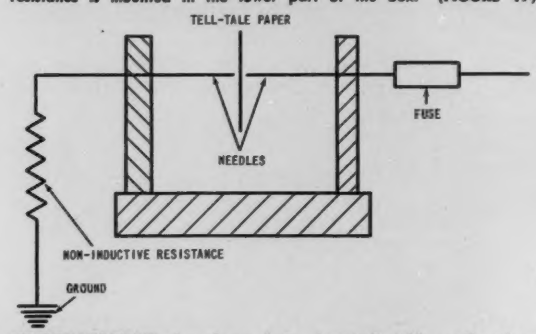
Line surges are damaging

Another thing which falls under the heading of maintenance and which is seldom fully understood by many persons in the electrical industry is the matter of voltage surges. Frequently the insulation on a certain machine may fail under conditions which appear definitely to indicate a weakness in the insulation. Actually the trouble may be caused by transient conditions due to lightning or switching, either switching in or out of the circuit. These conditions come in the form of traveling waves or surges of a potential sometimes as much as four, six, eight, ten, or more times the normal operating voltage of the machine. It is a known fact that many machines have been rewound and repaired time after time with the thought in mind that the insulation of this equipment was substandard, but where, in time, the condition was ascertained to be due to transient conditions caused by line surges

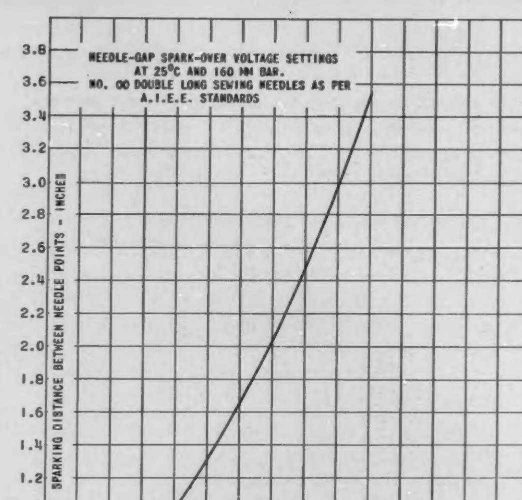
While a number of machines may be operating in a certain room in close proximity to one or the other it is possible that one of them may break down continually if surge conditions exist. This happens because the surge impedance of that particular machine is critical or in resonance with the impedance in that particular system or feeder so that the traveling surges follow the path of least resistance, causing difficulty in this one particular machine of a group of many others.



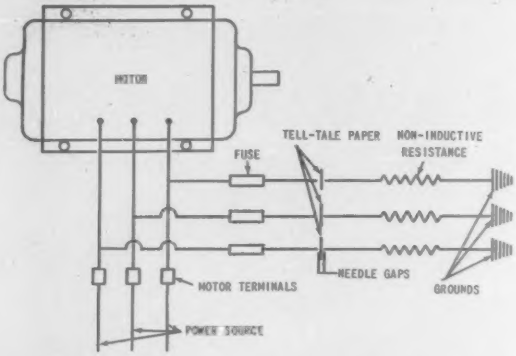
SPARK-GAP DEVICES consist of an assembly of a few simple parts, such as the two supporting blocks for the adjustable needles, two vertical prongs for the tell-tale paper, fuse, and terminal blocks. The non-inductive resistance is mounted in the lower part of the box. **(FIGURE 17)**



CIRCUIT DIAGRAM of spark-gap device shows adjustable needles whose spacing can be varied for different voltage settings. One needle is connected to ground through a resistance unit in the bottom of the box, the other is connected to the live copper terminal through a fuse. **(FIG. 18)**



NEEDLE-POINT SETTINGS (distance between needle points) for different spark-over voltages can be determined with the aid of the curve. For instance, for 25 kilovolts (25,000 volts) the needle points should be spaced 1.3 inches from each other. **(FIGURE 19)**



CIRCUIT DIAGRAM shows how three separate and distinct spark-gap units, like those shown in Figure 17, should be connected to detect voltage surges in a three-phase motor. (FIG. 20)

Where surges are suspected, their presence can be established definitely by the use of tell-tale needle point air gaps (Figure 17) placed at the terminals of the motor or generator in question. The circuit of this spark gap device is shown in Figure 18, while the settings or various spacings of the needle gaps are shown in Figure 19. For a three-phase machine, three needle gaps are connected on one side to the motor or generator terminals and on the other side to ground through a high resistance, Figure 20.

If the gap breaks down, it passes through the thin piece of paper. Daily or twice daily examination will indicate whether or not there has been a surge. As small size holes are not easily discernible, very careful inspection of the paper should be made.

For a 2,200-volt machine the needles might be set to first break down at approximately 4,000 volts. If a break occurs, then the points should be reset for 6,000 volts, then 7,500, 9,000, and so on.

If surges of 6,000 volts or higher are occurring regularly on this particular 2,200-volt circuit, then the engineering department should be notified so that necessary corrective steps can be taken. This entails a study of the whole electrical system, both inside and outside the plant, including all protective apparatus, such as lightning arresters, circuit breakers, fuses, ground circuits, capacitance placements, etc.

Conclusion — know your machine

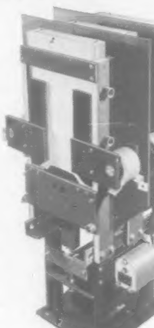
As stated previously, effective maintenance demands familiarity with an understanding of the structural and operating needs of a machine, knowing what to do, when to do it and the establishing of an upkeep or maintenance schedule and following it religiously. To perform efficiently and economically, machines must be accorded wholehearted attention; half measures or good intentions are not enough.

It should be evident that the problem of maintenance is always greatly enhanced if, when persistent difficulties occur, a reasonable solution to the cause of these troubles might be ascertained and overcome. Definite knowledge as to the cause of failures oftentimes is most important in that definite and satisfactory results or cures from the maintenance standpoint cannot be achieved in any other way.

Machines may be responsible for the better living we enjoy, but they still require conscientious attention to maintain their productive efficiency. They are still only as good as the men behind them.

New Products

New High Voltage Air-Break Contactor Announced for Heavy Duty Applications



A new high voltage air-break contactor has been developed for general a-c starting and severe duty cycle applications which require frequent starting, inching, reversing, plugging, or dynamic braking. This compact unit, requiring no more space than an oil immersed contactor, is especially suitable for use in rubber and steel mills, steel fabricating plants, cement and ore reduction installations, etc. Units already in service have cut maintenance costs to less than 10 percent of the amount generally allotted for upkeep when oil immersed contactors are subject to severe duty.

Despite its compactness, adequate insulation has been provided between all live parts and ground to permit direct mounting on a grounded plate or enclosure. Mechanical sturdiness and accessibility have not been sacrificed in any way to achieve compactness. Units are available with mechanical and electrical interlocks for reversing or dynamic braking.

Flange and Vertical Motors Offer Operating, Maintenance Economy

"Safety-Circle" motors, designed for long life and low operating cost, are now available for C and D flange and P-base mounting for close coupled applications. A heavy cast iron frame completely surrounds all working parts and provides extra protection against corrosion and distortion. Other features include a double insulated stator, a die-cast rotor, efficient ventilation, drip-proof end brackets, pre-lubricated bearings, precision machined feet, and roomy conduit box.

Drip-proof and splash-proof motors are available in sizes from 1 hp at 1,800 rpm to 20 hp at 3,600 rpm, in frames 326 and smaller. "Safety-Circle" design features and complete protection are also available in totally-enclosed non-ventilated, totally-enclosed fan-cooled, and explosion-proof types of motors.

New Motor Starter Resists Atmospheric Corrosion

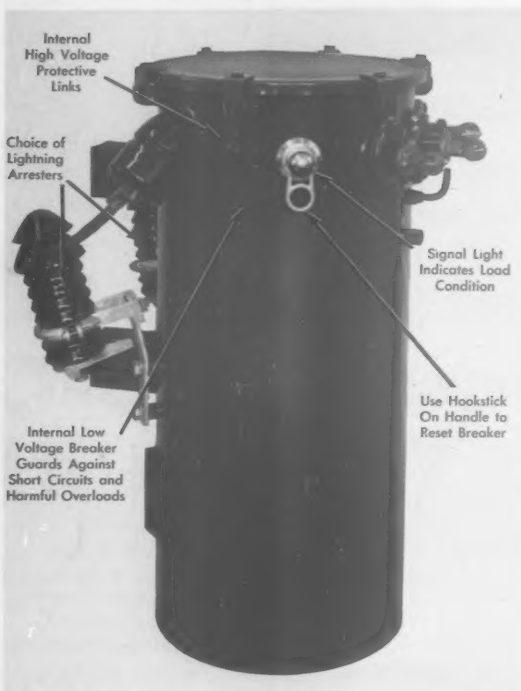
The recently announced wall-mounted, full-voltage starter is especially adaptable for use in chemical, liquid fuel, milling, coal handling, and other industries in which corrosive vapors or combustible, dust-laden atmospheres are present. Its entire mechanism is immersed in oil and sealed from the atmosphere. The new starter is weather-proof and can be used for outdoor installations. Its enclosure is entirely corrosion-resistant; the head casting is of aluminum alloy, all exposed hardware is stainless steel, and the steel tank is coated with aluminum paint on the outside and marine spar varnish within.

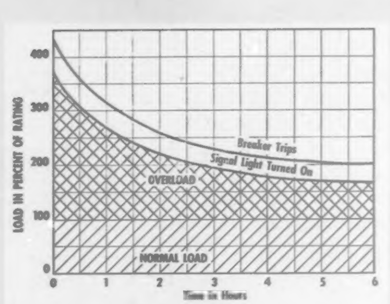
Built for simple installation and easy inspection, the starter controls squirrel-cage motors and the primary of wound rotor motors of 350-hp or less at 2,300 volts.

———O———

MORE FACTS about new equipment listed here can be obtained by writing the Allis-Chalmers ELECTRICAL REVIEW, Milwaukee 1, Wisconsin.

HERE'S *Premium* TRANSFORMER PROTECTION





Useful capacity of ACP transformer is increased with secondary breaker, actuated by either or both load current and oil temperature.

New ACP*
(*Allis-Chalmers Protected)
Transformers Give You...

- ✓ FULL ELECTRICAL PROTECTION
- ✓ MORE EFFICIENT LOADING
- ✓ SIGNAL LIGHT INDICATION
- ✓ GREATER SERVICE CONTINUITY

ONE OF THE BEST investments you can make is to be *sure* of maximum transformer protection against electrical damage... especially in concentrated load areas where service continuity is highly important. You can get this protection by specifying Allis-Chalmers ACP* transformers.

With these units, much of the normally unused safety margin capacity now becomes part of the actual transformer range, permitting loading much closer to the actual limit of the windings. Result — more kva output per kva transformer rating. Secondary breaker which is actuated by *either or both load current and oil temperature* protects against both sustained and short time overloads.

For additional information about *premium* ACP* protection —or other Allis-Chalmers protective transformer arrangements — contact your nearby A-C sales office, or write direct.

A-2834

**Allis-Chalmers, 848-A S. 70th St.
Milwaukee, Wisconsin**

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